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JOURNAL

OF THE

New England Water Works Association.

VOLUME XXI.

1907.

PUBLISHED BY

THE NEW ENGLAND WATER WORKS ASSOCIATION,

715 Tremont Temple, Boston, Mass.

The Fort Hill Press
SAMUEL USHER
176 TO 184 HIGH STREET
BOSTON, MASS.

INDEX.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XXI. March, 1907. No. 1.

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OBSERVATIONS ON THE TESTING AND USE OF PORTLAND AND NATURAL CEMENTS.

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[*Read December 12, 1906.*]

The present remarkable development in the use of cement is the direct outcome of the careful and persistent observations and experiments of our engineers, mechanical, chemical, and civil. There is not a structure of modern times built of natural stone or forms of burnt clay that has not been duplicated in cement. Cement is now meeting structural requirements hitherto impossible except by the use of iron, steel, and timber, and its advantages over the latter materials in the matters of cost, durability, and freedom from injury by fire and water are only just coming to be known. Time has shown that when cement is carefully selected and treated intelligently in the practical work of construction, enduring monuments are founded, to the honor and credit, not alone of the designer and builder, but, in justice be it said, to the pioneers and courageous supporters of this important industry in our country, who have persevered in face of many discouraging and adverse conditions until the American product is recognized as standard the world over.

While the rapid growth of the Portland cement industry since 1895, and the extended use of the material in all forms of construction, may be well taken as a tribute to its improvement and reliability, the better understanding and appreciation, not only of the users, but of engineers and architects as well, must also be

considered of the utmost importance. Hydraulic cements have been made and used for more than a century; and yet it has remained for investigators of comparatively recent years to throw much light upon the subject, and the light must be disseminated widely before the full benefit will be derived.

The adoption of a standard specification for Portland and natural cements during 1904 by the joint committee of the American Society of Civil Engineers and of the American Society for Testing Materials has proved a happy issue out of the maze of conflicting requirements which the manufacturer has met throughout the country in years past. It was perfectly natural, under such conditions, that doubt and suspicion of a product so little known should prevail among the uninformed. Before the adoption of the standard specifications, and even to-day to some extent, much conflict of opinion was found upon some of the most vital principles governing the acceptance of cement; each tester or engineer performing this duty was a law unto himself and exercised the full prerogatives of his official position in fixing requirements and interpreting results, oftentimes prescribing tests that were misleading and fallacious as an indication of quality, and which only served to vex and hamper the manufacturer; and in such cases an effectual barrier was set up between the very interests that have since combined and coöperated to the great benefit of all concerned.

In the absence of better information it may be natural for the user of cement to entertain with suspicion the statements of the manufacturer relating to the quality of a cement in question, but it seems obvious that with standard specifications and uniform methods of testing, combined with full and up-to-date information upon the results of the several determinations made, there would follow greater uniformity in the material, less opportunity for dispute, and a greater degree of confidence and mutual respect between men who are seeking the same attainments — excellence of material, design, and workmanship in all projects that mark the prosperity and progress of our country.

With an experience covering nearly eighteen years upon important hydraulic construction, I have found opportunity to observe many variable conditions affecting the requirements and

use of cement, and I know of no material entering into construction of which so much is expected that is subjected to the same or equal abuses; yet when a failure is recorded — happily very rare — how common it is to see the fault ascribed to the cement! The experienced and responsible manufacturer of cement believes in and encourages the intelligent testing of his product, and naturally of competing brands as well, and the time is not distant when he will *insist* upon tests being made in advance of use in reënforced concrete construction, or in other cases where he may be informed of either ignorant, careless, or dishonest methods, dangerous proportions, or the use of unsuitable materials to be combined with the cement.

An idea will obtain in the classroom, office, or laboratory which, if carried out or closely approximated in construction, would give excellent results; but how often this idea is forgotten or overlooked in construction, and crude—yes, cruel—methods of work are suffered! This can, under some conditions, be said even of cement-testing. Young men without previous experience or any knowledge whatever of the subject are sometimes selected for this work; and although they may have a high degree of intelligence, and be industrious and conscientious in their work, yet the best that can be said of such a selection is that it is more likely to result in causing a good cement to be questioned than in passing a poor one, although the latter chance is not remote; meanwhile, little consideration is shown the manufacturer or the reputation of his product.

Once asked to explain the difference in results obtained by two testers working together, using the same amount of water in mixing and following the same methods of molding, etc., I offered the somewhat parallel case of two cooks making bread from the same flour, same yeast, and same formula throughout, and yet the quality and appearance of the loaves would be quite unlike.

The personal equation cannot, perhaps, be removed in testing cement, but other conditions that vitally affect the results can be brought to a more uniform basis, and these in ordinary practice may briefly be summed up as the quantity of water used to produce a paste or mortar of given consistency, time and manner of manipulation, method of molding, temperature of water and air,

time and conditions of exposure in air and water, and rate of applying the load.

When tests are made under the instructions of the standard specifications by an experienced and skilled operator, they form a record valuable not alone to the work in which the material is being used, but to all users of cement who may have access to the results. Uniform tests, under a standard specification, serve to show:

First. Whether the material meets the standard or fixed requirements.

Second. Uniformity of the product tested.

Third. A comparison with other brands of the same material, which is invaluable at times when making a selection and computing the real relative net values.

Without a uniform specification and uniform tests thereunder, it is obvious that results could give no indication of uniformity of product, and a comparison with other brands or with the same brand tested at other points would be meaningless to a great extent. Training and experience are regarded as essential in any technical, mechanical, or professional work to produce results that are scientific, accurate, and dependable; the operator must know the full significance of his determinations or he will at times omit some detail or overlook a precautionary measure that may have a marked effect upon his results. Only trained, experienced men should be intrusted with the testing of cement on important public or private work where results are carefully tabulated and published in reports or otherwise circulated, and it is of great benefit and interest to all users of cement that we may have such results to refer to. The small or casual user of cement hardly finds it expedient or necessary to attempt a chemical analysis or test for specific gravity; in fact, when he is using a well-known and established brand he need feel little concern about this, and the tests for soundness, sand-carrying capacity (which he determines by tensile tests of sand mortars), time of setting, and fineness, all together have a bearing on the chemical proportions and specific gravity that means much to the experienced observer.

Tensile tests of *neat* cement are useless in determining the real relative strength of several brands of cement, and tests of

mortar of the proportion of 1 cement to 3 sand, by weight, should alone be considered in making comparisons. We *use* the cement with sand, not neat, and we want to know what to expect in our work. Many cements, both Portland and natural, give very satisfactory results in the neat test, but show marked inferiority compared with the best brands of both grades when tested for their sand-carrying capacity. Unless the standard Ottawa sand or crushed quartz be used throughout the test, we must recognize the fact that variable results will follow which are not due to the cement, but to the sand.

The effect of water in retarding the induration of cements and reducing their tensile strength, particularly at short periods, has long been known, and more or less information has been published as the result of experiments made.

The writer was led to make a series of tests on these lines during 1901, in somewhat more detail than anything he had seen published, and it is the result of this experiment, shown in the diagrams (Figs. 1 and 2) and in Table No. 1, that we will now consider. It may be stated that one man made the briquettes for the entire series, six for each period, at each interval in the amount of water used; the water used in mixing was at a uniform temperature of 63° F., and the temperature of the air averaged slightly under 70° F. and fluctuated between 50° and 75° F. Two briquettes of Am. Soc. C. E. standard form were gaged at a time, and beginning with the dry mixtures the molds were filled in three layers, each rammed successively until flushed, with a trowel. The ramming process continued until the mixtures became too soft, when the molds were filled by pressing in with the thumb and troweling. So far as possible the briquettes were allowed to set in air, under a damp cloth, for about two hours after taking the heavy wire, before immersion; this practice could not be followed uniformly, and some of the softer mixtures were allowed to set in air over night, and in a few instances the operator was obliged to wait until late in the night to complete his observations. In determining the rate of setting, the Gilmore needles were used. Care was observed to use the same sample of cement throughout the series, and this was taken from the storehouse of contractors engaged in the construction of large public work. The decimal

TABLE No. 1.

Showing Tensile Strength of Cements Mixed Neat with Different Proportions of Water.

Cement brand.	Water. Per cent.	Sieve Test; residue on No. 50.	Sieve Test; residue on No. 100.	Sieve Test; residue on No. 180.	Wire; minutes. Light.	Wire; minutes. Heavy.	Tensile Strength; pounds per sq. inch. 24 Hours.	7 Days.	28 Days.	3 Months.	6 Months.	12 Months.
"Giant" Portland.	13											
	14											
	15	0.15	5.4	21.2	12	207	371	655	875	941	720	787
	16	..	..	..	29	297	303	750	973	1 008	735	816
	18	..	..	..	80	355	260	649	773	831	645	748
	20	..	..	..	142	402	233	500	693	716	621	676
	22	..	..	..	268	473	184	546	635	658	601	589
	24	..	..	..	327	912	167	539	649	644	629	755
"Union" Natural.	23	0.1	4.6	10.2	13	32	212	251	252	311	275	356
	24											
	25	..	..	..	18	39	185	218	215	289	300	341
	27	..	..	..	21	42	150	188	220	257	272	314
	29	..	..	..	20	52	128	178	202	246	248	256
	31	..	..	..	21	57	112	173	199	224	259	309
	33	..	..	..	27	85	104	172	182	267	246	290
	35	..	..	..	38	137	93	121	178	260	286	319
	37	..	..	..	34	160	85	108	168	262	306	326
	39	..	..	..	67	233	85	119	202	252	371	400
"Atlas" Portland.	13	0.1	7.0	18.0	13	270	366	775	859	1 067	892	832
	14	..	..	..	18	303	404	780	891	972	852	781
	15											
	16	..	..	..	22	327	363	602	725	844	806	723
	18	..	..	..	15	383	308	570	723	785	728	724
	20	..	..	..	56	703	225	590	718	760	674	636
	22	..	..	..	52	833	166	554	649	731	643	604
	24	..	..	..	188	918	42	510	691	695	632	574
"Hoffman" Rosendale.	23	2.3	12.4	21.9	22	59	138	177	271	332	284	264
	24	..	..	..	..	78	125	141	264	342	309	310
	25	..	..	..	35	120	150	164	216	308	318	321
	27	..	..	..	49	143	117	116	194	305	345	272
	29	..	..	..	76	166	96	105	164	272	320	267
	31	..	..	..	117	212	72	72	159	270	371	225
	33	..	..	..	115	235	62	71	147	277	379	244
	35	..	..	..	127	400	50	64	112	245	318	315
	37	..	..	..	198	828	59	62	96	...	284	351
	39	..	..	..	260	1 057	54	56	85	...	355	364

Memoranda. — Results shown are the averages of six briquettes made.

scale of weights was used in gaging, the graduate glasses being carefully calibrated to agree, and the briquettes were broken on a Fairbanks machine of late pattern, the clips having roller bearings of composition metal.

Chemical analyses of the cements here considered were not made for this test, but the characteristics of the brands named are doubtless well known to many, and will be only briefly referred to. The Atlas and Giant brands of Portland cement both come from the Lehigh district of Pennsylvania, and, in their chemical composition, are in quite close agreement. The "Union" natural is also made from the Pennsylvania cement rock of the Lehigh district, is light in color, and its composition is quite unlike the "Hoffman," which is dark in color, being made from the magnesian limestone of the Rosendale district, New York. "Union" more closely approaches the Portland standard in composition, and differs from the "Hoffman" noticeably in its lime and magnesia content, having about 50 per cent. lime and 2 per cent. magnesia, while the "Hoffman" has about 36 per cent. lime and from 16 to 18 per cent. magnesia, which is characteristic of nearly all the New York Rosendale cements. The low magnesium content, together with the very fine grinding of "Union," cause it to be more active and quicker setting than "Hoffman," and this is well shown in the table and diagram, particularly in the wetter mixtures.

As might be expected, this difference in the cements would be in greater contrast when combined with sand in concrete mixtures than in neat cements; and, in fact, it was the dissimilar results in practical work of construction that led to this experiment. I regret that the experiment did not also include mortar mixtures in the proportion of 2 sand to 1 cement for the natural cement, and 3 sand to 1 cement for the Portland, wherein conditions more closely approximating the operations of every-day practice would obtain.

From personal acquaintance with a recent large work of concrete construction the writer is forced to the conclusion that when any reliance must be placed upon the cohesive strength of Rosendale cement within six months, or perhaps longer, depending upon the exposure and local conditions, great care must be exer-

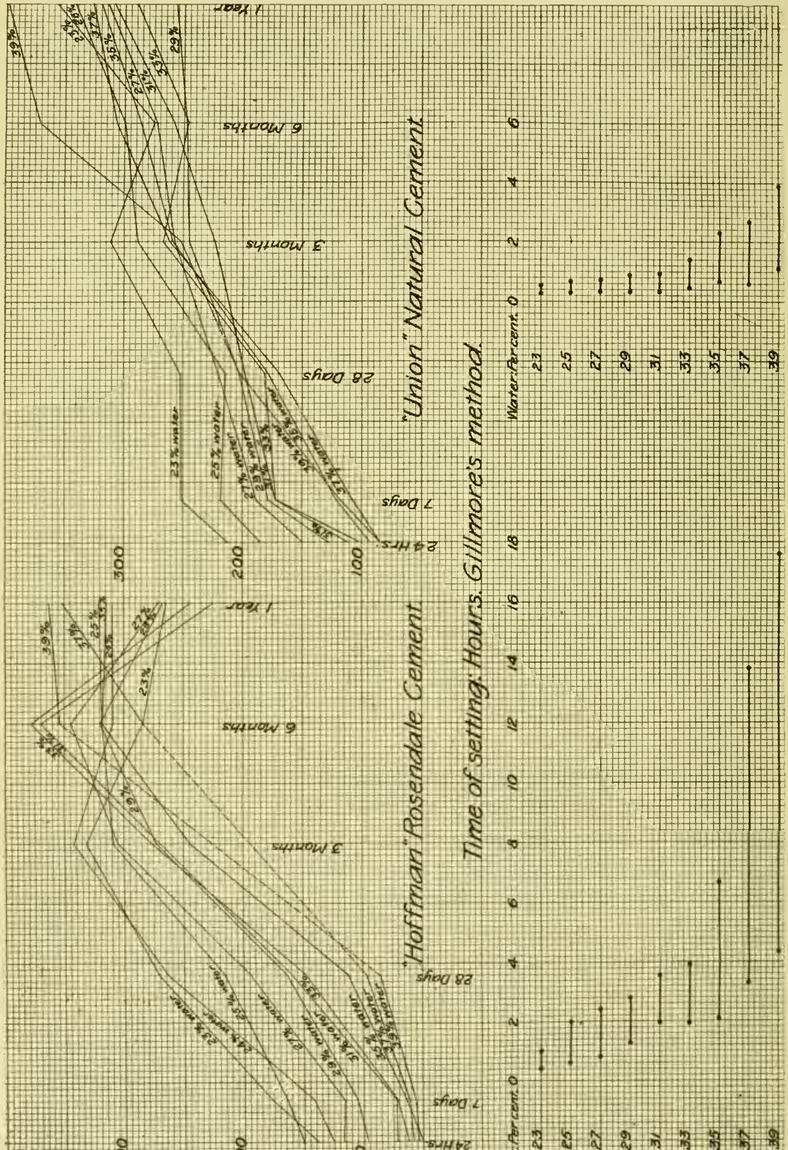

"Union" Natural Cement.
"Hoffman" Rosendale Cement.
Time of setting: Hours. Gillmore's method.
Tensile Strength: Pounds per sq. in.
Water-Per cent.
24 Hrs.
7 Days
28 Days
3 Months
6 Months
1 Year

FIG. 1.

cised in proportioning the amount of water used; or, in the present day of wet concretes, in selecting a cement that successfully withstands the deteriorating influence of an excessive amount of water.

In the diagram of tensile results (Fig. 1), the dryer mixtures of the " Hoffman " cement show superiority up to the 28-day period, at which time it is quite marked and uniform; the gain in strength between the 24-hour and 7-day periods appears slow, and grows slower as the amount of water is increased; the improvement between the 7-day and 28-day periods is better, but the rate of gain appears generally in favor of the dryer mixtures; the gain in all mixtures between this and the 3-month period appears quite uniform, and develops a rapid gain for the wetter mixtures; after the latter period inconsistencies develop, and between six months and one year only the 37 per cent. and 39 per cent. series show any appreciable gain, and the wettest mixture appears superior at the end of the year, the others generally showing a falling off in strength, for which I can offer no explanation.

In the " Union " cement series the dry mixtures generally appear superior at the 24-hour and 7-day periods, the rate of gain is quicker and quite uniform; as in the Portland cements, the gain in strength of the wetter mixtures is more rapid between seven days and twenty-eight days, the wettest mixture having passed four of the series next below, and all of the series being closer together than at the two earlier periods; at three months only the 23 per cent. and 25 per cent. series held their superiority, the wetter mixtures rapidly overtaking all others and being in close agreement, with the exception of the 31 per cent. series, which made a slower gain; after this period peculiarities develop for which no explanation can be offered, but the uniform rate of improvement is noticeable in all instances, and the results at one year are better in each case than at any preceding period, the 23 per cent. and 33 per cent. series showing a falling off between three months and six months with a good recovery at one year.

In the Portland cement series (Fig. 2) the rapid and uniform improvement between twenty-four hours and seven days is noticeable, but the dryer mixtures generally hold their superiority; this is noticeably uniform in the " Atlas " cement at all periods; the maximum strength was attained at three months,

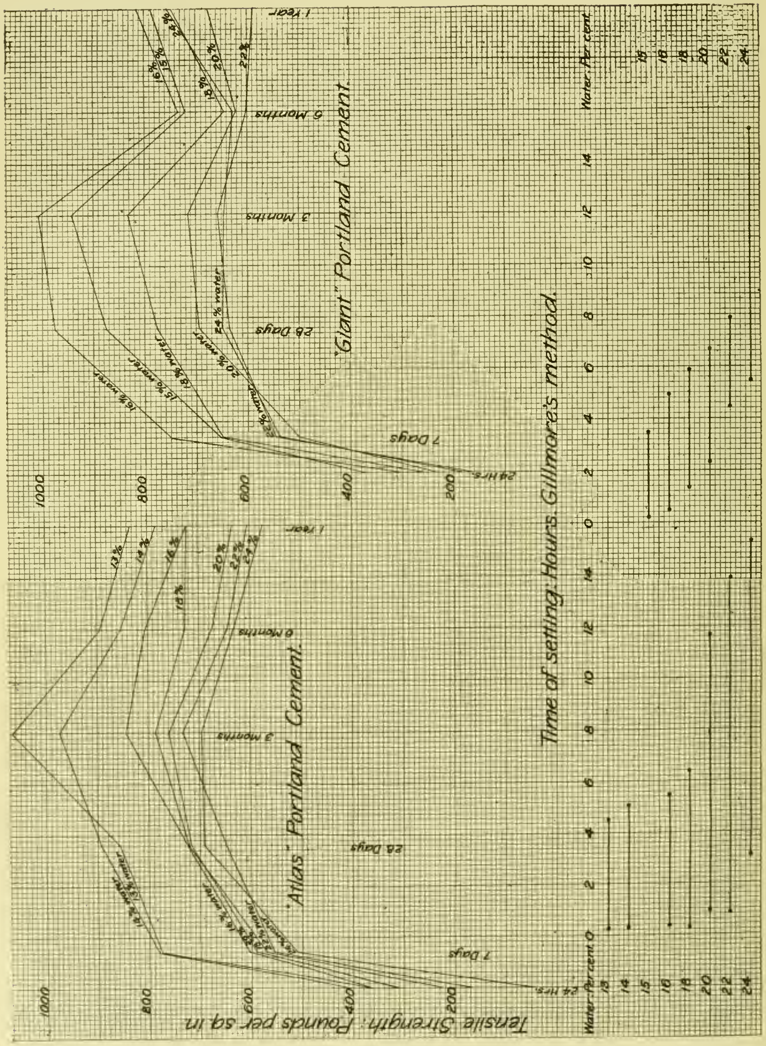

"Giant" Portland Cement.
"Atlas" Portland Cement.
Time of setting: Hours. Gillmore's method.
Tensile Strength: Pounds per sq. in.
24 Hrs.
7 Days
28 Days
3 Months
6 Months
1 Year
Water Per cent

FIG. 2.

after which, and up to one year, there appears a steady falling off in strength; but from three months on the dryer mixtures are uniformly better.

The "Giant" cement also attained its maximum strength at three months, at which period the dryer mixtures also appear uniformly superior, with the exceptions of the 15 per cent. series; and judging from the results of this series throughout the test, it would appear that in this case there was not quite enough water used to perfect the crystallization of the cement. The "Giant" cement also shows a falling off between three months and six months, but a good recovery after this latter period in all but one series, 22 per cent.; and the wettest mixture, 24 per cent., passed the three series next below at one year, — two of them in fact in six months, — and between six months and one year it showed a more rapid gain than any of the other series.

The personal equation is apparent in these tests, as in any tests of the tensile strength of cements, but every effort was made to secure consistent and uniform results, and I will repeat that one man made the test throughout the entire series for the four cements named.

Cement or concrete construction, with or without steel reënforcement, is coming rapidly into favor, supplanting steel, stone, brick, and lumber in all forms of construction, and it is but natural that mistakes and failures sometimes attend the efforts of the inexperienced; and certain retribution is in store for the dishonest workers; but it is a remarkable tribute to this comparatively new system of construction that so few failures have been recorded during the phenomenal growth of the industry.

We find recorded failures in all styles of construction, brick, stone, steel frame, and timber, as well as concrete, but because of trade jealousies and the hostility of some labor unions, the failures in concrete construction are the best advertised at the present time. It is significant, however, that practically every instance of failure in concrete has occurred during construction, and has been chargeable to carelessness or incompetence. Unlike iron and lumber, concrete is not destroyed by fire, nor does it rust out or decay, but in fact becomes stronger and more durable with time, and the scores of splendid examples of this plastic con-

struction throughout the country are telling proofs of its merit and adaptability.

Low first cost is not necessarily ultimate economy, and if concrete did not perform its duty well and stand the test of time, other materials would surely supersede it. It is of the greatest commercial importance to all in the industry that quality should be a first consideration. You well know how the slightest imperfection in concrete work is pointed out by hostile interests as a sign of inferiority or failure, and a small crack which would be overlooked in brick work is viewed by the uninformed as a forerunner of sure and sudden collapse. Use only high-grade cement and select your sand with care, and beware of sand containing loam or clay; clean siliceous sand, ranging from fine to coarse, gives the best results; test it in combination with your cement before using. The ballast or coarse aggregate should also be clean, and of varying size in order to reduce the voids to a minimum. Gravel and igneous rocks furnish the best stone for concrete, much better than limestone for fireproof construction. For crushed stone, use a $\frac{1}{4}$-inch mesh dust jacket on the sizing screen; you will then have a more uniform product. The amount of dust varies with the size, shape, and character of the stone crushed, and also upon the rate of feed into the crusher, the speed of the crusher, and the degree of moisture in the stone. Stone dust, if clean, is better than most sands, but should be accurately gaged as sand, and more care is required to thoroughly incorporate it with cement because of the large percentage of fine material contained.

If crushed stone is stored or binned, as in most work requiring reserve stock, a more uniform mixture can be drawn from the bins when using, if the dust be excluded, since the latter serves to pack or cement the stone together, and alternating loads of coarse and fine will surely result in loading from heaps or drawing from bins.

In securing quality, thoroughness and care of mixing and placing concrete are of the utmost importance; *carelessness in placing will undo the work of mixing.*

Proportions of cement, sand, and stone will vary, depending upon the work to be done, but it is well to keep in mind:

First. That the stone voids should be a little more than filled with sand, and the sand voids a little more than filled with cement if strength is desired.

Second. That the voids in ordinary sand vary from 30 to 42 per cent., so that if leaner proportions than 1 cement to 3 sand be used, the cement will not fill the voids and the mortar will be porous.

Third. Accurate gaging is essential to uniform results.

A word as to consistency or amount of water used:

Wet concrete is the order of the day, and while I believe in using too much rather than too little water, still, in my judgment, much concrete is made too wet, and if in this condition much tamping, spading, or forking be done, the coarse aggregate will be driven to the bottom of each layer placed and a very unequal distribution of cement throughout the mass will follow. Except in the presence of very intricate reënforcement the mortar should be of a consistency to easily support the coarse aggregate and admit of light tamping. *Excess water serves to undo the work of thorough mixing.*

With a view of determining the variability of wet mixtures, the writer made the following test this past year:

Gang molds were placed vertically over each other, eight in all, to contain a layer 8 inches deep; the joints between molds were sealed with a thin layer of a mixture of white wax and tallow to prevent the escape of water. A high-grade Pennsylvania Portland cement was used in the proportion of 1 part cement to 3 parts of standard Ottawa sand, by weight, gaged with 20 per cent. water. Fine annealed wire (32 gage) was inserted between consecutive molds, and when the mixture had partially set these wires were used to cut the gang molds apart, and the operation was satisfactory in producing perfectly formed briquettes. The briquettes were then allowed to remain in the molds over night, under a damp cloth, and were then removed and immersed in water until broken.

The consistency of this mortar compared closely with that of much of the wet concrete now used, — dryer than some I have seen used in large work. When the molds were filled the mixture was churned and worked with a glass rod about ¼-inch in diam-

eter. The following results (Fig. 3) are the average of three briquettes, a total of 48 being in the series; No. 1 briquette is from the top layer and No. 8 from the bottom.

The purpose of this experiment would have been accomplished in the test for one period alone, but it was deemed inexpedient to make the trial for any time short of one month. The inferiority of the briquettes in the bottom layers is clearly apparent, there being a maximum loss in strength of 117 pounds at twenty-eight days and 151 pounds at forty-five days. It would appear entirely reasonable to assume that a greater variation will be found in a 7-day test than in either of the above two noted.

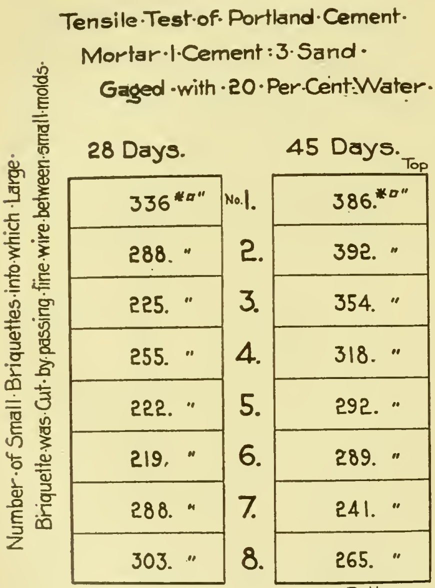


FIG. 3.

Concrete, to be of the utmost value, should be a true monolith of uniform strength throughout; this is of vital importance in beam, girder, and slab construction, and is not difficult of attainment.

This would seem to suggest that the idea of proper consistency is worthy of serious consideration, and further experiment, in the line of compression tests also, may bring forth interesting facts.

Table No. 2 and the diagram, Fig. 4, are also given showing the tensile strength of Portland cement mortar mixed in the proportion of 1 cement to 2 sand and gaged with different percentages of water, ranging from 8 per cent. to 20 per cent. Sand known locally as "Plum Island" sand was used. This is a dredged sand, very clean, selling at $1.60 per ton delivered. High-grade Pennsylvania cement was used. The results given are the aver-

age of three briquettes. Percentage of water used was determined on the combined weight of cement and sand. Briquettes were immersed in water until broken after remaining twenty-four hours in a moist air closet. The injurious effect of using too little water is plainly evident in the 8 per cent. series, and requires no further emphasis. Up to six months the superiority of the dryer mixtures, excluding the 8 per cent. series, is quite uniform,

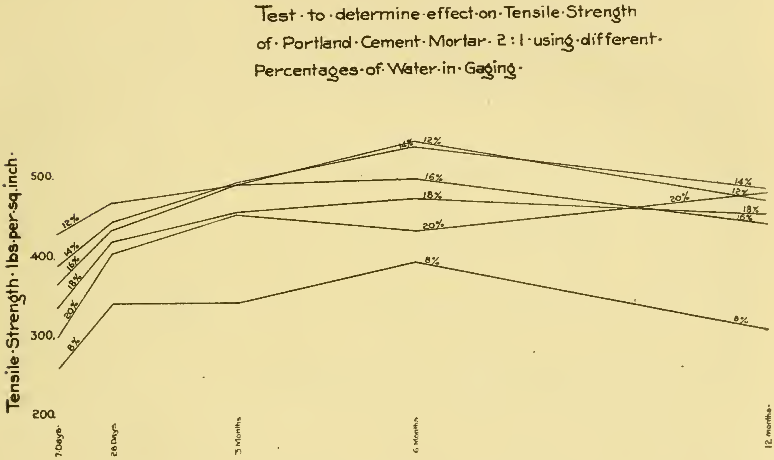


FIG. 4.

and it would appear that from 12 to 15 per cent. water would give the best results in a mortar of this composition, namely, 1 cement to 2 sand. Fourteen per cent. water will yield a very plastic mortar if properly tempered.

TABLE No. 2.

PORTLAND CEMENT MORTAR, 1 CEMENT TO 2 SAND.

	Tensile Strength, Pounds per Square Inch.					
Water — per cent.	8	12	14	16	18	20
Time of Test.						
7 days	261	433	392	368	338	301
28 ,, ...	344	470	447	436	422	407
3 months	344	490	494	491	457	454
6 ,, ...	392	543	536	497	472	430
12 ,, ...	300	463	478	434	446	474

It is gratifying to note the growing appreciation of the important part sand plays in all cement work, for in very many instances poor results are directly chargeable to the sand used. No cement will improve properly if mixed with very fine sand, and results will vary depending upon the characteristics of the fine material. It must also be kept in mind that an intimate mixture of cement and fine sand is very difficult to attain, and a thorough distribution of cement throughout the sand voids is absolutely essential to good results.

Sand that looks good is not always above suspicion, and the following instance will serve to show the importance of testing the sand before use. An important hydraulic work was begun last year in New Brunswick, and the contractors and engineers had congratulated themselves upon having what appeared to be an ideal deposit of sand and gravel for concrete work. The cement was thoroughly tested with standard sand and found satisfactory. When everything was ready, an active start was made, and considerable concrete was placed before any doubts arose; it would not set up, however, in a week's time (or longer, it proved), so the cement was immediately tested again, with favorable results, and then some of the sand was examined. On the washing test it was noticed that a slight opalescence was imparted to the water, remaining in suspension several days, but leaving practically no deposit on sedimentation. The cement was then tested with this sand before and after washing, and the trouble at once located. The sand and gravel were both washed thereafter, and good results followed.

Table No. 3, on page 17, is added showing the tensile strength of cement mortars in the proportion of 1 part sand to 1 of cement, by weight, for Rosendale or natural cements, and 2 parts sand to 1 cement for the Portland. A siliceous sand was selected for this test, carefully screened to the sizes noted, and combined in the proportions given in the table. The test was made to determine the relative value of sand grains of different diameters, in combination with cement, and also to study the effect upon the tensile results of adding fine material.

Few unwashed natural sands are free of dust, of a loamy or clayey nature, containing high percentages of organic material,

TABLE No. 3.—Tensile Strength of Cement Mortar with Sand Grains of Different Diameters.

Results given are the average of six briquettes.

Sand gage per cent. used.				Natural cement mortar 1:1.								Portland mortar 1:2.			
				Water per cent.	"Union."			Water per cent.	"Hoffman."			Water per cent.	"Giant."		
No. 30.	No. 20.	No. 100.	Fine.		7 days.	28 days.	6 mos.		7 days.	28 days.	6 mos.		7 days.	28 days	6 mos.
100	..	..	..	17	156	193	352	15	115	163	314	10½	286	288	412
..	100	..	..	17	151	194	349	15	118	146	286	10½	294	331	473
..	..	100	..	17	153	187	340	15	91	110	257	10½	201	226	294
..	..	..	100	17	100	123	307	15	71	76	186	10½	129	159	223
80	10	10	..	17	154	210	358	15	94	124	301	10½	361	380	486
70	15	12½	2½	17	142	190	332	15	86	107	254	10½	301	303	428
60	20	15	5	17	143	192	342	15	83	107	285	10½	307	311	419
50	25	17½	7½	17	140	208	345	15	80	89	291	10½	391	400	538
40	30	20	10	17	133	197	362	15	90	82	296	10½	350	355	475
30	25	30	15	17	123	191	329	15	78	77	266	10½	362	359	478
20	20	40	20	17	128	199	318	15	66	73	285	10½	317	374	480
10	15	50	25	17	122	201	324	15	68	72	221	10½	291	354	488
50	..	..	50	17	108	193	317	15	62	70	239	10½	247	287	351
50	50	..	..	17	154	222	323	15	82	107	316	10½	440	408	542
50	..	50	..	17	150	210	344	15	78	88	290	10½	309	336	438
25	25	25	25	17	125	183	302	15	74	68	250	10½	279	337	447
	Crushed	quartz.													
40	..	60	..	16	179	256	3 mos. 355	14	93	100	3 mos. 142	9½	257	331	3 mos. 351

Memoranda.—All proportions and percentages determined by weight. Natural sand used, first passed through No. 8 screen and residue excluded. No. 30 sand passed No. 20 screen and caught on No. 30 screen. No. 20 sand passed No. 8 screen and caught on No. 20 screen. No. 100 sand passed No. 30 screen and caught on No. 100 screen. "Fine" is clean white sand sifted through the No. 100 screen.

and in specifications calling for sand clean and sharp and free from fine material, the importance of excluding this deleterious agent is recognized, but it is not always possible to enforce this exclusion absolutely; and from mechanical analyses of a large number of samples, and casual inspection of sand in use at various points, I am satisfied that much sand is used that contains 5 per cent. of dust, and a good deal that carries as much as 10 per cent., and even more in some instances.

The fine material passing the 100-mesh screen used in this test was obtained from a clean, white, siliceous sand; and if, with increasing amounts of this material, a falling off in tensile results appears, it can in no sense be taken as a *measure* of what would follow by using sand containing a dust of loamy or clayey nature, but it is in a way suggestive. The cements used in this test were of the same sample as in the other tests previously referred to.

The sand mortar test is the true basis upon which to judge the value of a cement, and I believe the proportion of sand to cement should be the same as that employed in the actual work of construction. Unfortunately, this was not carried out in the above test of the natural cements for the reason that results were desired for comparison with results of previous tests in the same laboratory, in which the crushed quartz or standard sand was used in the proportion of one part sand to one of cement.

Explanation of the results is hardly required; it will be noticed, particularly in the case of the natural cements, how uniform and constant is the falling off in strength at the 7-day period as the amount of fine material increased. This tendency, in the case of Union cement, disappears at the 28-day period, at which time rather remarkable uniformity is found in all the combinations, except the 100 per cent. fine; serious retardation in the improvement of the Hoffman, with the increase of fine material in the sand, is noticed between the 7-day and 28-day periods, the mixtures containing over 5 per cent. fine remaining almost latent for this time, three of the combinations showing an actual loss, while four make a small gain, the average gain being 2 pounds; a rapid recovery is found, however, in these combinations between the 28-day and 6-months' periods, and it is to be regretted that longer time tests were not made.

A tabulation of the results, excluding the series in which all fine and crushed quartz were used, is herewith given:

	7 Days.			28 Days.			6 Months.		
	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.
Hoffman......	84	118	62	99	163	70	277	316	221
Union	139	156	108	198	222	183	336	362	302

The effect of the fine material upon the Portland cement is not so noticeable, even at the shortest period, except in the series with 100 per cent. and 50 per cent. fine, and no parallel can be drawn between the test with Portland cement and the results with Rosendale cement, using the same combinations of sand.

Cement users are coming to select their cements with more discrimination than ever before; their increased knowledge of the subject, and the more extended use of the material, show this to be necessary, and the natural result, owing to the struggle for commercial supremacy among the manufacturers, will be a better and more uniform product.

The chemistry of cement is an intricate problem, and an academic knowledge of it without sufficient practical experience has resulted and will result in much trouble to the manufacturer and user as well.

It is well said that " Experience is the best teacher."

DISCUSSION.

Mr. Frank L. Fuller. I have had some experience in the use of concrete in the construction of reservoirs, mostly covered reservoirs, and its superiority in that kind of construction is very great. With brick and stone fixed methods of construction must be followed, for the material can be used only in certain ways, but with concrete we have a wider range. It is also true that to a greater degree unskilled labor can be employed, and this means a reduction in the cost of the structure. I think that better reservoirs can be constructed for the same amount of money, of better design, and of larger capacity, than could be built several years ago, even when prices of labor were less than they are to-day. This material is particularly well adapted for use in covering reservoirs and similar structures. The time for-

merly required to cover such a structure with brick can be reduced probably one half or even two thirds by the use of concrete, and the result will generally be better.

I think the point was well taken in regard to the separation of the cement from the aggregate in the case of too wet a mixture. Of course the tendency is, when the mixture is too wet, for the stone and sand to separate from the cement. Nevertheless, some work that I have done where the mixture has been very wet has been entirely satisfactory. A better face can generally be obtained to exposed work by using concrete that is rather wet.

Prof. William P. Mason. Mr. President, I should like to ask for a little information with reference to a matter which came up in connection with the cement question not so very long ago. You will remember that Hillebrand and others published in the *Engineering News* some years back methods for the examination of cement from the chemical side, but, so far as I can find out, they did not differentiate between the combined silica and the mixed sand. Now the question which came up of recent date was whether certain cement bricks were up to the specifications. The specification called for a certain percentage of sand in the finished brick. I do not know how to make the determination of sand as against the rest of the silica except to separate them physically; and after the thing has once set it isn't an easy matter to physically separate the sand from the comminuted brick. The results are a good bit unsatisfactory. I would like a little information upon this point,— that is, the determination of sand in a set cement brick.

Mr. Larned. I will admit that there is a good deal of mystery about that, and it has feazed a great many very careful observers. An occasion for that determination arose in Boston within a comparatively short time, when the question of the proportions of concrete was raised by one of our city authorities, and some of our well-known experts were selected as a committee to examine the concrete and report on the proportions. The only way that I know of by which a close approximation — and it is only an approximation — can be made, is to determine the lime. We know that in the standard brands of Portland cement the pro-

portions of silica and lime are fixed within pretty close limits. They have to be to conform to the standard specifications. With the lime determined, and a proper allowance made for the silica to combine with the lime, then allowance can be made for the added silica, which is the sand. It is only an approximation, but it is the closest which can be made, I think.

There is one thing about consistency of cement which I did not touch on, which may be of interest to you. The bulk of concrete used in years past has been hand mixed, and in very many cases to-day it is necessary to so mix it. But I am very glad to see mechanical mixing coming more generally into use and being more generally required. It is a very difficult matter to combine sand and cement. They are naturally repellent of each other, with entirely different physical characteristics, and it takes vigorous work to combine them. You well know that in practical stone laying or brick laying operations the mortar tender is selected for that work who is a good, big, strong, husky fellow who can keep his hoe working in the mortar tub, and the more he works the mortar, the more he cuts it and churns it and whips it with his hoe or spade, the better condition it is in for the brick mason to lay his stone or his brick in. It is fatter. Now that quality of fatness means that the cement and sand are well combined, well incorporated with each other. In the case of hand-mixed concrete, where a dry mixture of cement and sand is first made, and then combined with the stone and the water added afterwards, the very first application of the water to that mixture means separation between the cement and the sand. You can see it, it is visible, and it is almost impossible in the presence of a coarse aggregate to bring the materials together again with shovels. They are, of course, knocked together in the hand-turning, but as a rule hand-turning is indifferent; the material is just rolled over. If it was slapped down, getting somewhat the same action that we get in mechanical mixing, it would be better.

To show how less water can be used and produce a concrete of quite a wet consistency, I might remind you of this: in mechanical mixing, if you use, for instance, twelve per cent. of water and hold it in your mixer for four or five or six additional

turns, it will compare very favorably in consistency with concrete in which you might have used sixteen per cent. of water and turned it out in a shorter time. It will be just so in hand mixing. You well know that concrete on the board oftentimes looks fairly dry, but by the time it is in the forms and subjected to ramming and spading and forking it flushes. That is due to the additional working. That same thing happens in the mechanical mixer and makes possible the use of less water.

Mr. Leonard Metcalf. One question occurs to me to ask Mr. Larned, and that is, if he made any determination of the character of the foreign material which was washed out by the water in this New Brunswick case of which he told us?

Mr. Larned. There was no analysis made. It appeared to be of a clayey nature. That was sufficient, and inasmuch as it seemed to be accountable for the trouble no further interest was felt in it.

Mr. William E. Foss. I should like to ask Mr. Larned whether he can tell us the cause of this little efflorescence which sometimes appears on brick masonry, whether it is due to the cement or the bricks or to lime, if they use it, or the coloring matter which is sometimes added?

Mr. Larned. Efflorescence is usually due to the washing out or dissolving of the alkalies in cement, soda, potash, and magnesia, and, as a rule, is more noticeable in Rosendale cements than in Portland cements, particularly the Portland cement of present manufacture. It is more pronounced, of course, in wet or damp locations, and has been successfully resisted by the application of waterproofing compounds, either in the mortar or on the exposed surfaces of the work.

Efflorescence sometimes originates or is added to by impurities in the brick, and occasionally it may be detected, not only through the joints of the brick work, but on the face of the work; this is due to absorption by the brick of the impregnated water from the mortar.

THE EXPLOSION OF THE SARATOGA SEPTIC TANK.

BY PROF. W. P. MASON, TROY, N. Y.

[*Read December 12, 1906.*]

On January 26, 1906, the cover of one of the four septic tanks of the Saratoga sewage plant was totally wrecked by explosion. The tank covered an area of $91\frac{1}{2} \times 51\frac{1}{2}$ feet, and was built of concrete, with a concrete cover supported by columns of the same material.

Six manholes pierced the cover, and these were closed by disks of cast iron held in place by their weight alone.

The explosive effect was uniformly distributed, the entire cover having been sheared from the side walls and from the supporting columns. Although the iron manhole covers were thrown to great heights, the heavy concrete roof of the tank probably did not rise over 10 or 15 feet and then fell back in a state of utter ruin.

At the time of the explosion, one of the local theories advanced to account for the disaster was the malicious introduction of some high explosive. Aside from the improbability of any one venturing to commit such an act, the character of the explosion renders that theory inadmissible by reason of the fact that a high explosive would have caused serious local shattering of some one part of the structure and not a wreck of great uniformity over the entire area of the tank. It is now pretty generally admitted that the cause of the accident lay in the firing of an explosive mixture of septic gas and air.

The question is, How was the match applied? The location of the plant is in a remote spot and there was but small opportunity for the act of some passing smoker to have occasioned the trouble. In the opinion of the writer the primary ignition was caused by phosphine.

We all remember the timeworn lecture experiment wherein that spontaneously combustible gas is permitted to bubble through water and burst into flame when the surface is reached. Could

a small portion of phosphine have been generated by the action of organic matter upon the phosphates present in sewage, then the flame following its escape from the liquid of the septic tank would surely have been sufficient to have kindled any explosive mixture of gases which might chance to have been present. Can such a formation of phosphine be looked for? It is certain that I should not care to attempt a chemical equation to represent the reaction, but it is equally certain that I have upon one occasion observed large bubbles of gas, each the size of an orange, rise from the river bottom off the New York City docks near the sewer outfalls and that such bubbles did burst into flame upon breaking the surface.

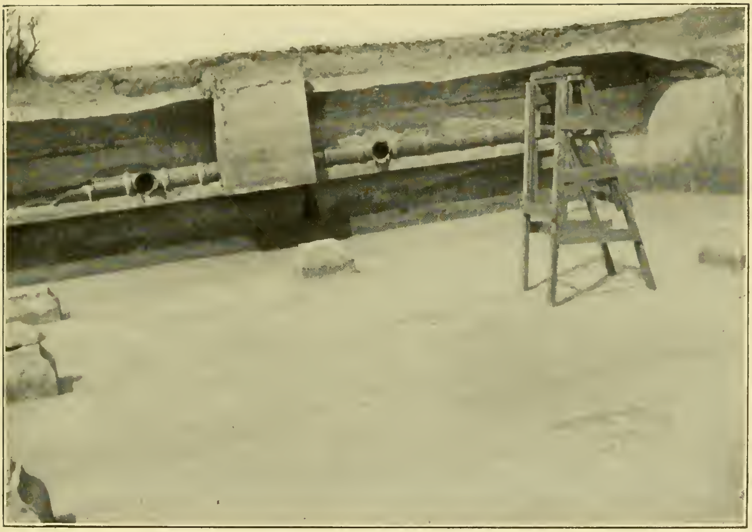
The suggestion that phosphine was the cause of the Saratoga septic gases becoming ignited seems reasonable, and the question arises, What is to be done to guard against a repetition of the accident?

Allowing the probable rarity of phosphine formation, yet the possibility of its appearing is ever present, and we consequently look for safety toward the prevention of an explosive mixture of air and septic gases. It is scarcely news to tell you that, given a combustible gas, the mixture of the same with air will not be explosive when the mixture is made in all proportions.

As shown by Kinnicutt, the septic tank gases commonly contain about 75 per cent. marsh gas, with the balance of practically non-combustible materials. For complete combustion, marsh gas requires ten times its own volume of air; therefore, on the above percentage composition, 1 000 cubic feet of septic gas would require 7 500 cubic feet of air to burn it, making the total volume of explosive mixture 8 500 cubic feet. Any decrease or increase of the above proportion of air would lessen the intensity of explosive power, until finally a non-explosive mixture would result.

Sealing of septic tanks, as practiced during the early days of the art, has been abandoned, and air can now gain admission to the space between the cover and the sewage. It would seem wise, therefore, to so order the ventilation of that space as to keep the evolved gases continually so diluted with air as to avoid the formation of an explosive mixture.

PLATE I.



THE SARATOGA SEPTIC TANK AFTER THE EXPLOSION.

DISCUSSION.

Prof. Leonard P. Kinnicutt.* I agree with Professor Mason in a great deal that he has said, and do not believe the explosion was caused by the introduction of an explosive into the tank. There is no question that there may be often an explosive mixture of gases in a septic tank, composed of methane generated from the decomposition of organic matter in the sewage, and of atmospheric oxygen, and the explosive force of this mixture when ignited would depend on the ratio that existed between volumes of the methane and the oxygen. The important question is, How did this mixture become ignited? Professor Mason believes that the ignition was caused by the formation of the phosphite of hydrogen, which is a liquid at ordinary temperatures, and which immediately takes fire when coming in contact with oxygen.

Theoretically, this explanation is a perfectly reasonable one. In sewage there is a comparatively large amount of calcium phosphate, and also what are known as reducing bacteria, — bacteria which take away oxygen from various mineral substances. For instance, we know that nitrates are reduced to nitrites and sulphates to sulphides, and there may be a variety of bacteria that reduce calcium phosphate to calcium phosphide, which would cause the formation of the liquid hydrogen phosphide. If this liquid phosphide were formed it would ignite spontaneously, and might thus have been the cause of the explosion. There is, however, one objection to this theory, which is, if phosphates in sewage are reduced to phosphides, we ought to be able to prove the fact by laboratory experiments. We can prove that nitrates are reduced to nitrites, that sulphates are reduced to sulphides, yet so far we have not been able to obtain phosphides from phosphates, and though I have made very many experiments with sewage sludge, I have so far failed to obtain any trace of calcium phosphide.

These experiments are still being carried on in my laboratory, and may yet give positive results. Still, until we are able by laboratory experiments to show that there are phosphate-reducing bacteria, a simpler cause of the explosion may be considered,

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namely, that the explosion was caused by a lighted match or smoldering cigar accidentally coming in contact with the gases in the tank. According to Professor Mason's account, one of the employees of the sewage plant had just stepped off the top of the tank when the explosion occurred. Of course this may only have been a coincidence, still I do not think that anything that Professor Mason has said precludes the idea that this man was the cause of the explosion, that he was smoking or had lighted his pipe while on the tank and had thrown either the smoldering ashes from his pipe or the still lighted match in such a way that it might have caused the ignition of the gases inside the tank. This explanation seems to me more probable than that the explosion occurred through the formation of liquid hydrogen phosphide.

President Sedgwick. I take it that Professor Mason only intended to suggest his explanation, and not to consider it as established or proved; but it does seem to me that his observation in New York is of very great importance. If a man has seen a river taking fire, he has a right to assume that there is something there which sets it afire, and it does seem to me that such an observation by such an observer ought to have great weight.

Mr. Eddy, I think, has had some experience along this line in Worcester, and we would be very glad to hear from him.

Mr. Harrison P. Eddy.* I realized some years ago, when I was trying to master the subject of chemistry under the instruction of the learned gentleman at my right [Professor Kinnicutt] that there was a good deal of theory about it, and to-day I am convinced that I was entirely right at that time, although it was then very difficult to convince him that that was true. [Laughter.]

This theory of Professor Mason's is certainly exceedingly interesting, and is worthy of very careful consideration and study; because, if what he suggests can happen, — if it is possible that that thing can ever happen, — we are up against a pretty stiff proposition, not only in connection with septic tanks, from which for safety we can omit the covers, but with our sewers and our cesspools and the deposits of mud under our wharves and under some of our buildings. It is a question if we shall be safe any-

* Superintendent of Sewers, Worcester, Mass.

where, except out in some place like the vicinity of the Saratoga disposal works where there are not many neighbors.

It does seem a little strange that we should have been dealing with septic tanks, where we have this gas all the time, and where we have the phosphorus all the time, for so many years, and that we never should have met just these conditions before. We are familiar with the fact that bubbles of gas come up on our septic basins, — large areas of the water are covered with bubbles of methane, — and why is it that they are not ignited? Why is it that we have never seen them burning in the open air? If there is a gas coming up which produces a flame, how does it happen that this thing can be constantly with us and yet never before have produced any effect which has been seen?

There are a number of things which it would have been interesting to have learned to-day about that explosion in Saratoga. We should like to know, for instance, whether the attendant was a man who ever smoked; whether he had a friend with him who ever smoked; whether he ever used a lantern in examining the tank, and various things of that kind. I presume the reply to all that might be that the man didn't smoke and that he didn't have any matches with him that day; but if he did it is very possible that he might have dropped a match which might have ignited a piece of paper or something which dropped into the tank. There are a great many possibilities.

When I was reading about this explosion some time ago I was very much interested, because I had mentioned in one of my reports the possibility of explosions in septic tanks, — not due to phosphine gas, however, — and it occurred to me that human nature is a pretty doubtful proposition, and any one who has had to deal with men in charge of filter plants, or in charge of gangs of men, knows that it is difficult sometimes to get at the real facts. To illustrate, I will just mention this incident which occurred some little time ago in connection with one of my foremen, who is a very trustworthy man, and whose veracity I ordinarily wouldn't question very much. I went upon the job one day, and after looking at him carefully and observing signs of intoxication, I said, "Pat, how many men have you got here?" He had some 30 or 40. "Well," he said, "I think I have got 14."

I said, " Pat, what is the matter with you? You have been drinking? " " No, sir, haven't taken a drop." [Laughter.]

Now that is the thing we are up against all the time in handling men; and while this Saratoga man may say that he did not have a match or lantern or cigar or pipe, there is still the human element which enters into the problem. I think Professor Mason's theory is very pretty, but I don't know but there is, at least, just as much ground for thinking that there might have been ignition from some outside source.

Professor Mason. Mr. President, I cannot help but wonder how high that man would have gone had he touched the tank off with a lantern or a pipe. You see there was no chance of anything getting in except through the manholes, and a man would of necessity have been on top of the tank in order to have dropped anything into its interior.

Mr. John A. Gould.* I think that Professor Mason is right about this. Our chemist, Dr. Wing, has made numerous experiments trying to ignite explosive mixtures with a cigar. We have signs up all around our works, " No smoking allowed," but Dr. Wing has proved conclusively that it is impossible to light an explosive mixture of illuminating gas and air with a cigar, even when the cigar is at a bright glow; so I do not believe it would have been possible for a cigar, if it had been dropped into the tank, to have ignited the gas, unless it was more dangerous than illuminating gas.

Professor Kinnicutt. Speaking of the ignition of explosive gases, there is no question that an explosion in Lowell some six years ago of a mixture of carbon bi-sulphide and air was caused by a glowing cigar. And in experiments I made at that time a mixture of carbon bi-sulphide and air was easily set off, not merely by a lighted cigar, but also by a lighted cigarette. Furthermore, there have been explosions of septic tanks in England, and in two cases it appeared that workmen were smoking. Whether it was conclusively proved that the explosion was caused by these workmen I do not know, but it was so stated in the current literature.

Mr. Gould. I think the danger from smoking is in lighting

* Assistant Engineer, Boston Consolidated Gas Company, Boston, Mass.

a cigar or pipe; that is, it is the match which does the harm. That is the danger from smoking around gas works. It is not from smoking, but from dropping a lighted match.

Professor Kinnicutt. I should like to ask you, Mr. President, whether there are any bacteria, so far as you know from your laboratory work, that will reduce phosphates?

President Sedgwick. I don't know of any, no. I should like to ask Mr. Phelps if he knows of anything of the sort?

Mr. Earle B. Phelps.* None have come under my observation.

Mr. E. S. Larned.† Isn't it a fact that they have a good many explosions in sewer manholes?

President Sedgwick. I was about to say that explosions in sewers are not rare, but in these cases very frequently — although not always — men have been down in them. This suggestion of Professor Mason's, — which I take it he offers only as an hypothesis, a working hypothesis, and a very interesting one it is, — if investigated and followed up might explain a number of things. I can't myself get away from that observation which he made in New York, when he saw the bubbles come up and burst into flame, and it seems to me that until those who are opposed to his ideas can explain that observation in some way, his hypothesis has at least one leg to stand on.

Mr. Frank A. Barbour.† I do not know how exact Professor Mason's knowledge as to conditions under which the explosion took place may be, but my information at the time was that there were two men at work on the disposal field. One of these, the superintendent, was in the laboratory; the other had just come off the top of the septic tank. It is some time since I have given much thought to the matter, and I have had no opportunity of visiting Saratoga since the explosion, but if my memory serves I had a letter at the time stating that the second man had just passed over the edge of the embankment at the time of the accident.

When I left Saratoga after building the works — after being in charge of the plant for a year — arrangements were made to continue the observations of depth of scum and deposit in the

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* Massachusetts Institute of Technology, Boston, Mass.
† Civil Engineer, Boston, Mass.

tanks twice each week. These measurements were taken with a Fowler sludge gage through the openings in the roof of tanks. It would, therefore, not be an unusual thing for a cover to be removed and for the attendants to be working around the openings in such a way as to permit the entrance of some external agent accountable for the explosion. I am practically certain that both of the men who were on the plant smoked, and smoked pipes, and I think it very possible that in some manner a match was dropped into the tank, perhaps in the act of replacing the cover, in such a way as to postpone the actual ignition until the attendant, luckily for him, had time to retire beyond the danger limit.

My feeling is, therefore, that the explosion was caused by some external agency — perhaps by a match; possibly by spontaneous ignition of oily cotton waste. At all events this explanation is indicated by the fact that one of the attendants had within a few seconds of the time of explosion been on top of the particular tank in which the accident occurred. There are four (4) tanks exactly similar in construction, and it is a remarkable coincidence, at all events, that with the same sewage treated for several years, and at the time of explosion all four tanks filled with sewage of the same character, if the accident was due to a process of chemical decomposition inherent in the sewage, the explosion should have occurred at this time and in just the particular tank over which one of the attendants had been working or passing. While not intending to deny the validity of Professor Mason's explanation, — and his observation made at New York is interesting, — the burden of the proof is certainly on him.

It is a matter of common knowledge that under such conditions, as stated by Mr. Eddy, it is difficult to obtain information from men who have passed through such an experience, and I am not surprised that no actual reason for the explosion has as yet been put in evidence.

As a matter of interest it may be stated that the roof of the tank was replaced as originally constructed and the tanks continued to be operated in the same way as before the explosion — the opinion of the local authorities apparently being that the explosion was due to some foreign cause. Smoking around the tanks is, however, prohibited.

President Sedgwick. I am reminded of what is well known to us all, that explosions in sewers are generally regarded as explosions of illuminating gas which has leaked into the sewer; and in what I said a moment ago about sewers blowing up, I meant that the match might have been phosphine, or something of that kind, although the cause is generally traced to some man who has gone down with a lantern or has thrown down a match. Dr. Mason's paper is a contribution to our theory of these matters, and I am sure is of interest even to those members of the Association who haven't much to do with sewage, because septic tanks are now common, cesspools are everywhere, and sewer explosions are frequent, so that we want to know all that is knowable about these things. It is true that we don't know it all yet. There are reductions and combinations and permutations of chemical compounds possible under the influence of bacteria which we do not yet fully understand. It is well to keep an open mind in these matters, and we are very greatly obliged to Professor Mason for coming here and broaching this interesting hypothesis. I take it that he does not care to make it any more than that at the present time. Does he wish to add anything to what has been said?

Professor Mason. No; there is nothing to be added. That tank blew up, and something touched it off. It may have been a match, as has been suggested, but I believe that it may have been phosphine, and one reason why I so believe is because of what I saw on the New York wharf. The bubbles there burst into flame before my eyes; that is beyond peradventure. Now if anything of that kind should have occurred in the tank, it would have accounted for what happened. That such a thing did occur I do not venture to say; I offer it only as a suggestion.

Mr. Barbour. I should like to ask Professor Mason what he thinks of the possibility of such bubbles coming through the existing depth of floating scum, which, in the preceding year, you could almost walk on? I do not know how it was at the time of the explosion, but when we were taking our sludge measurements in the preceding year it was with difficulty that we could shove the gage through the dried surface of this scum.

Professor Mason. Well, inasmuch as the septic gas passes

through the scum, the presumption is that gases of other kinds will pass as well. Septic gas passes into the space between the top of the sewage and the under side of the cover, and the phosphine gas, if formed, would naturally follow the same channel.

Mr. Phelps. Mr. President, I am fully as much interested in the remedy for this thing as I am in the theory as to the cause of it. Professor Mason mentioned two possibilities, only one of which he considered, — that is, either having too much air to allow of an explosion, or too little air and too much gas. I think perhaps Mr. Barbour could tell us which would be the easier condition to maintain. It seems to me it would, perhaps, be the better way not to ventilate the tank at all, but to keep it air tight and prevent the admission of air, rather than to attempt to thoroughly ventilate it.

Particularly does this seem better in view of the fact brought out by Professor Mason that a mixture of 10 parts of air with one of gas is required for an explosion. It strikes me that this is just about the mixture which one would get by ordinary ventilation.

Mr. Barbour. I think the ventilation of the tanks could be easily arranged; it certainly is a safe thing to do, and in future I shall make provision for ventilating the tanks, although there will be numerous instances where we will continue to use roofs as we are doing this year.

Experience has shown that open tanks are fully as effective as covered tanks, but it is to be remembered that in many places the appearance of the plant is the controlling factor. This was particularly the case at Saratoga, where the vicinity of the plant, while isolated, is a favorite resort of many of the summer visitors.

The covers on the tanks were simply of plate iron, about $\frac{1}{4}$ inch thick, and were not constructed so as to be air tight, being just set in a cast-iron frame. At the time of the explosion these covers may have been coated with ice in such a way that the gas was practically trapped under the roof. In certain experiments made in England, — described in one of the reports of the Royal Commission on Sewage Disposal, — no gas pressure in the septic tanks was found, the gas apparently diffusing itself through the masonry.

METER REGISTRATION.

BY ARTHUR N. FRENCH, SUPERINTENDENT WATER COMPANY, HYDE PARK, MASS.

[*Read January 9, 1907.*]

In reading the JOURNAL of this Association for December, 1906, I was interested in a little paper presented by Mr. George A. Stacy on "Pumping without an Air Chamber" and the discussion upon it. In that discussion Mr. Stacy spoke of a happening in his experience, when one of his patrons thought he had discovered a water meter which was registering when no water was passing through. It occurred to me then that some experiences of mine along that line might be of interest to some of the members of this Association who had not happened to meet with the same difficulties.

One experience which I had was along the lines suggested by Mr. Stacy's friend. I did have a water meter which registered cubic feet of water on the dial when absolutely no water was passing through the pipes. Of course we all tell our patrons that it is a physical impossibility for a meter to register without the passage of water, but I have had three cases in my experience when it has occurred, and I have experimentally caused meters to register without the passage of water. It is an unusual condition when such a result is accomplished, and to do this experimentally it is necessary to understand how it is done, and to provide the necessary conditions.

The season of 1899 was a very dry one, and my company found it necessary to add to its source of supply and to its pumping plant. A tract of land in another locality was secured, wells were driven, a station built, and a pump installed. The wells were 21 in number, $2\frac{1}{2}$ inches in diameter, and the pump was a horizontal direct-acting compound of 2 000 000 gallons daily capacity. It was and is so rigged that it could be operated as a duplex pump, or by changing the valve connections either side could be operated by itself. It was found best to always run the pump in this latter manner, as the 21 wells would not furnish water fast

enough to make it profitable to operate the pump as a duplex. The water plunger is 14 inches in diameter and the stroke 24 inches. The pump is operated at about 32 strokes, or 16 revolutions per minute. As our system is that of direct pumping, with a standpipe for the excess, the operation of this pump makes a considerable amount of fluctuation in pressure on our mains and piping system. There is a surge at every stroke, and the pressure will vary about 9 pounds at the pumping station, and a mile distant the fluctuation of pressure will be about 3 pounds.

We began to operate this plant regularly in December of 1899, and some time in the following year one of our patrons called my attention to the action of the water meter in his house, which, he declared, was registering water when none was being used. He said that he could hear the meter operate in the dead of night. Complaints that " there is something the matter with the meter " are of such frequent occurrence that the statements of my friend were not taken very seriously. He persisted, however, and I went to his house. Everything was all right. The plumbing was tight, no water was being drawn, and the meter was not registering. I thought the incident was ended, but in a short time I saw my friend again, and he repeated his statements. I visited the house several times, and at last I found the meter actually in motion. I saw it go, and heard the piston thumping gently at about the frequency of the strokes of the pump at the pumping station. I satisfied myself that no water was escaping at any point in the house. All of the water piping and fixtures were in plain sight. I watched the meter and it registered one tenth of a foot on the test dial in a few minutes. After that I went there frequently and noted these same conditions. Then I took out the meter and set another of the same make. That would register just the same. I reversed the meter, setting it backwards, and left it there twenty-four days, in which time it registered forward 240 feet. The meter was of a type which does not revolve backward.

Of course we soon thought that the pulsations of the pump might be the cause of the trouble, but the only way in which these pulsations could produce such an effect would be through the existence of an air chamber of considerable capacity in the

piping of the house, allowing each stroke of the pump to compress the air and force a little water in through the meter, turning the pointer on the dial forward. In the interval between the strokes the air chamber would force an equal quantity of water back through the meter, which could not turn backward. I examined the plumbing for such an air chamber, but could find nothing which could possibly provide such a chamber except a hot-water heating plant in the cellar. The house stands on high land, and the pressure on the mains at that point is only 30 pounds. The hot-water heating plant of which I spoke is located in the cellar, and furnishes heat for a small greenhouse and for four radiators on the ground floor of the house. Water is connected with this plant from the house pipes directly, and is left on all of the time, and there is no expansion tank, so that there is always a pressure of 30 pounds on this heating system, and when it is fired up the expanding water must be forced back through the meter to the street main. It has no check valve. I think there was an air cushion somewhere in the heating plant, though I could not find one. Air may have been trapped somewhere in the return pipes where we could not find it.

After satisfying myself that the meter did actually turn without the consumption of water, I took it off and substituted one the piston of which will turn either forward or backward, and have had no further trouble there.

I was not quite satisfied with the knowledge gained by observing the above case, and decided to make an experiment. I therefore rigged up a rude testing plant at our new pumping station, where the static pressure is 98 pounds, and the fluctuation due to the stroke of the pump, 9 pounds. I took a kitchen hot-water boiler and mounted it in a hydrant house. I attached a pipe to the hydrant nozzle, set a meter, and attached the other end of the pipe to the hot-water tank, from which there was no outlet. A picture of the arrangement is shown in Plate I. When the hydrant was opened, the hot-water boiler filled with water to within about 9 inches of the top, that 9 inches being compressed air, making a splendid cushion. With this arrangement I tested several kinds of meters. It will be noticed that the meter in the picture is an old-fashioned plunger piston meter. That ran

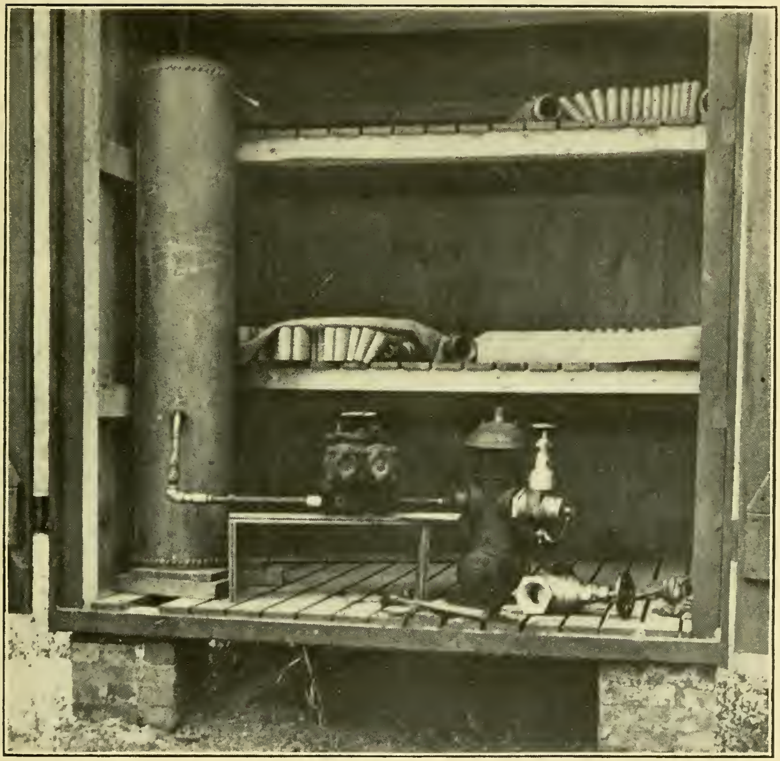
beautifully under the test, registering one foot on the dial every $1\frac{3}{4}$ minutes, or 70 strokes of the pump. Another meter registered a foot in $32\frac{1}{2}$ minutes. I found that any type of meter which would turn backward would not register water under this test, but any meter which was so constructed that it would not turn when water passes through it backward, would register under that test. I found also that if a good check valve was set with the meter, no kind would register.

I have had two other cases of this same nature. In one case I found the air cushion in a long pipe running to a lawn hose faucet and another long line running to a stable, neither of which had been emptied of air when the water was last turned on.

Another rather mystifying experience which I have not yet fully worked out, but which I suspect is due to the same operation of the surge of this pump upon an air cushion somewhere in the piping system, is the peculiar action of a 2-inch meter on a fire standpipe. This is located in a block which has stores on the ground floor and flats on the two floors above. The standpipe is 2-inch, and has nothing connected with it except hose outlets on each floor, to which hose is always connected. There is no leakage, for if there was it would show on the floors. I have repeatedly examined the piping, and I believe there is no other possible outlet. No water has been used from this standpipe in the past six months, yet the meter now reads 1 847 feet *less* than it did six months ago. There is a regular decrease in the reading month by month. The meter is set correctly and is in good order, having been overhauled not long since. This meter is of the type which will turn either way; and I should like some member of this Association to explain how it can turn backward under the circumstances and not forward. It is possible that there is something in connection with the gearing which tends to drag a little when going forward, and allows free turning backward.

It is, indeed, a cold day when there is not some sort of a puzzle on hand in connection with meters. I once had an ordinary $\frac{5}{8}$-inch meter which all at once began registering backward at about ten times the speed at which it should register forward. On removing it and overhauling, I found that one wheel in the intermediate gearing had become loose on its shaft, fallen down, and

PLATE I.



APPARATUS FOR TESTING METER REGISTRATION UNDER FLUCTUATIONS OF PRESSURE.

engaged a different pinion below, reversing the travel of the dial hands, and driving them ten times faster.

Another $\frac{5}{8}$-inch meter set on a dwelling-house service puzzled us for some time by registering up to about 65 feet and then going back and commencing over again. It seemed to have a certain prejudice against recording above 65 feet on its dials. We watched it for some time. The owner of the house fell under suspicion, though he didn't know it. On taking out the meter and examining it, we found in the train of gears attached to the pointers on the dial one wheel which had one missing tooth.

In several cases I have had a meter become set so that it would not turn, caused by the wearing of the end of a shaft in the intermediate gear, so that its pinion would drop down a trifle and engage two gears at once.

I hope none of the gentlemen present will form the opinion from this little paper that I am opposed to water meters. The contrary is true. In our plant about 40 per cent. of the services are metered, and if I were a magician the other 60 per cent. would be within the year. I would rather have this little paper taken as an indication that meter troubles come to every one, and no person in charge of a water-works plant which is beginning the work of installing meters should become discouraged by puzzling things in connection with them. The puzzles will be found solvable, and it will be found that there are not more of them than is the case with almost any machine.

DISCUSSION.

THE PRESIDENT. Now is your chance, gentlemen. Here is something right off the bat [laughter], and if you can't catch it you are not in the game. I am sure Mr. French will be very happy to have a lively discussion. Of course we want to hear from the meter men.

A MEMBER. Mr. Tilden has the ball, Mr. President. [Laughter.]

MR. J. A. TILDEN.* Of course freaks will sometimes appear in the best regulated families and among the best regulated

*Mechanical Engineer, Hersey Mfg. Co., Boston, Mass.

machines. I believe it is not an unknown thing for such a staid and reliable machine as a locomotive to start up of itself and run amuck. Somehow or other the throttle valve gets open, nobody knows how, and the thing runs away. Still we have a great deal of confidence when we ride behind one of these dignified and stately machines that we will get to our destination in due time, and the few occasions when they do run amuck do not discredit them in our confidence by any means.

There are in use in the United States to-day possibly somewhere in the vicinity of 2 000 000 water meters, and I venture to say without prejudice that, taken as a machine, taken as an instrument, taken as a class right straight through, they are reliable and are so regarded by the water works fraternity at large. These little things which Mr. French has told you about do happen, but it is very, very rarely. The conditions under which they occur are peculiar, and they have to be extraordinary. Mr. French has gone into the matter very carefully and explained to you just how these meters register when no water is passing through them. Of course that statement is not exactly true, for meters register because the water *does* pass through them, and they do not " unwind " the registration simply because they are of a type which can only operate by the water passing through them in the usual direction. Repeating, then, the meters of which he spoke registered because water did pass through them, but they didn't " unwind " when the water passed back through them.

There are several kinds of meters which will act in that way. It was at one time considered to be quite an advantage for a manufacturer to produce a water meter which was capable of registering in only one direction. Some inventors have gone so far as to put special ratchet devices on the gearing, so in case the meter was reversed by an unscrupulous water-taker, or a Chinaman [laughter,] he would have to pay for the amount of water which did go through, and couldn't unwind it so that the water company would owe him. I suppose if some of our good friends, the superintendents, were so disposed, they could tell of numerous instances where other types of meter, those which register equally well in either direction, have been maliciously removed from their connections and set in the wrong direction,

so that the registration has been very materially less than it was at the time of the previous reading, making virtually charges against the water department instead of charges against the consumer.

In systems where there is direct pumping, and where there is the liability of the formation of an air chamber, and one of the several kinds of that type of meter which Mr. French has described, it will work as he has shown. The air chamber in this particular case that Mr. French brings to your attention, that is, the one in the private dwelling house, is not far to look for. In a hot water system it is almost impracticable to fill the radiators completely full of hot water; there is no true circulation in the upper part of the loops of the radiators. The top part of every radiator is a true air chamber, so that with each pulsation of the pump there will be a marked flow of water into the system, and at each recession of the pump there will be a marked discharge from the hot water system back into the water works system; and a meter of that kind, — that is, the kind that won't unwind, — will go forward, as he says. He has gone so far and so carefully into the matter that he has explained fully how it may be avoided if you are ever up against that sort of a thing. Of course the simple presence of a check valve will prevent any possibility of working backward, when you are confronted with the air chamber problem.

In this particular case something is allowed which I think all water works superintendents will agree is extraordinary, that is, the direct connection of a hot water system in a private house with the water works system, without a check valve and an expansion chamber; in other words, allowing water works pressure to circulate throughout the hot water system, so that no expansion can take place without driving the water back into the water works system. The general plan, as you all know, is to provide an expansion chamber, or to go into a tank and then from the tank into the hot water system and then into an expansion chamber. The condition which Mr. French mentions was most extraordinary. In a great many places it would not be allowed, and I venture to say you would have to go a great way to find another such case.

He speaks of another type of meter. I might say here that I perhaps ought to have some reluctance to speak on this subject, because my good friend Mr. French is the superintendent of the water works in the town in which I live, and presumably no other meters are used in that town but my own. [Laughter.] I wish to say to you, however, that such is not the fact, and therefore my reluctance is not so great as it might otherwise be. Mr. French has had experience, as is stated in his paper, with a variety of types. There is no one type there which has gone through all his experiences, so I can speak on the subject in a broad way. He mentions a 2-inch meter which, due to the presence of the air chamber again, is steadily showing a less amount, month by month. That is a type of meter which will work both ways. That is, this particular meter is a current type of meter and will work either way, — by the water passing through it in the regular direction or with the water passing through it backwards. Now, being a current type of meter there is one direction in which it will work a little freer, a little easier, than it will in the other; that is to say, it will not register exactly the same amount of water forward that it will register backward, or *vice versa*. It so happens that this particular type of meter is a little more sensitive running in the reverse direction, so that while the meter is forced forward by the surging of the water against the air a certain amount, it recedes by the surging of the water in the other direction a little further back than where it started from in the first place, and the differential between the two is in favor of unwinding, which is the term Mr. French uses. Of course the condition is entirely abnormal there and is instantly relieved by the placing of a check-valve either in front or back of the meter. I don't know the name of the meter, and I am just talking in a general way because Mr. French said it was a current meter, and some of the current meters have this characteristic of measuring more in one direction than they will in the other.

The difficulties in connection with the intermediate gearing of which he speaks, that is, the wearing and dropping down of one gear into another, are common to all meters in which the motion of the piston is communicated to the dial by intermediate gearing. I think, however, I can say with confidence that it is

a most extraordinary occurrence. From my personal knowledge of and experience with thousands of meters, it is something which occurs, as you may say, only once in a generation. It has occurred, it does occur, but it is a most extraordinary freak, and occurs so seldom in the hundreds of thousands of meters that it may practically be disregarded.

The little incident about the meter which has such a strong dislike to register more than 65 feet without starting over again is really very funny. I can see how that might happen. I don't know whose meter it was, but it can happen to the dial of any meter made by any manufacturer. I apprehend it comes about in this way, and any one of you gentlemen can prove it by experiment. Suppose, if you please, it is a 6-dial meter; if you lock firmly the last dial, the last spindle, as it might possibly be by corrosion, and then undertake to wind it up, you get a very powerful spring action. One hundred thousand turns of the first spindle will make one turn of the last spindle, and with the last one rigidly fixed you can turn and keep on turning until the whole thing is a powerful spring, and the time comes when something has got to go, and that something is a tooth in the gear. The minute that tooth goes everything slips right back to its original place, everything goes right back to zero again, and proceedings start up as before until the broken tooth is reached and then the thing goes back again.

However, I am very glad that Mr. French does not bring up these things for the purpose of discrediting water meters, and I feel that neither as an associate nor as an active member do I need to stand here and apologize for what I believe, and what I am sure we all believe, is a most creditable record and a most creditable showing on the part of that marvel of mechanical ingenuity, the modern water meter. [Applause.]

Mr. George A. Stacy.* Mr. President, a few days ago my inspector came in and said, "We have got another mystery." Those mysteries go only as far as we make an investigation and search out the facts, and I can say that there has been no mystery about any water meter we have had yet that we have not been able to solve. In this case the trouble wasn't with a meter, but simply

* Superintendent of Water Works, Marlboro, Mass.

with the dial of the indicator on a plunger elevator, and the explanation was so simple that it shows how easily you can be fooled if you are not careful in making your investigation. This dial registers up to 10 000 000. The elevator has been in use perhaps four years and the indicator got up to several hundred thousand. The next time the inspector went there it registered 35. He came back and notified me, making the remark about its being another mystery. I said, " Well, the best thing you can do with that is to keep your eye on it; somebody has been monkeying with it." The next time he went there it had gone up from 35 to 95,000, and I said, " You had better take it out and bring it down here and we will examine it."

He brought it down. The cap that covered the face of the dial had been broken, and I set the indicator on the desk and began working it around, trying to find out if there was a slip in the gear or if a pinion had dropped down, but everything appeared to be intact. Taking hold of the hands and trying each one, and holding it up to a strong light, everything appeared to be in perfect order and in perfect mesh, and you couldn't start a thing anywhere. On most dials, as you know, in fact on all dials I had seen previous to this one, the hand on the end of the shaft is just put on and soldered, and if the solder breaks the hand becomes loose and will drop off at the least movement. But these hands were put on a little differently; a little more work had been put into them, and they were fitted on a little further; not exactly rivetted on, but so that the hand would turn clear around and not come off or show a break in the solder. They were stiff enough so you could move the gear back and forth and put about all the purchase on you would think ought to be put on to the hand without disturbing the joint.

The inspector came in at night and he says, " Have you found out the trouble? " I said, " No, I haven't; I guess we have got to look further than this." And just as I spoke I pressed pretty hard with my hand and I started one of the hands; and I found then that there were four of the high reading hands, which, by putting on pressure enough, I could keep turning around, but still they were tight enough to do the recording. The explanation was simply that, the case being broken, the everlasting small boy

had been playing clock with the thing, as we found afterwards; and he had set it so that sometimes they owed us and sometimes we owed them, and it got so we didn't know where we were. Thus the mystery was solved; and it was a very simple thing, like all the rest, when you get at the truth of the matter.

Mr. Edwin C. Brooks.* Mr. President, speaking of connecting hot water systems directly with the water pressure, it becomes necessary in many apartment houses, where there is no room for a tank above the upper story, to put the hot water system for the house on to the direct pressure. Of course in Cambridge we discourage as much as we can the connecting of a hot water system direct, but nevertheless it is done frequently, and in order to give a satisfactory pressure of hot water on the upper stories of these houses it is necessary to do it.

We always calculate in setting a meter to make a canvass of the house and, if the hot water tank is connected directly to the water service, to put in a check valve. And there we often meet with opposition. We say to the householder, " We don't propose to furnish a drain for blowing off your hot water back into the main, and we don't propose to have you run hot water through this meter and ruin the discs, or anything of that kind "; so we put on one of the swing checks, and it has resulted in this: the cautious owners will go and purchase a 75-cent pop-valve and put it on to the hot water system and thereby make their plant a little safer than it would be otherwise. I think if check valves were more generally applied to all metered services it would result in a better condition of the meters, although I am free to say that we don't always have check valves which operate as well as we would like to have them. We endeavor to connect nothing but brass into the check-valve body, and in that way get rid of the corrosion that will always take place when an iron nipple is screwed into a brass fitting.

In regard to the registration of meters we all have complaints. An inspector will come in and say that a certain meter is not showing any use of water and we had better look into it and see what the trouble is; and we find that on some of the higher hands the pinions are stuck in the plates, and that they go up to a certain point

* Superintendent of Water Works, Cambridge, Mass.

where either the meter stops because it can't break the gear, or else a tooth of the gear goes. I must say that it is astonishing what power some of these little disc meters have for tearing things to pieces. I have often wondered at the amount of injury they can do to themselves, but still such is the fact. I think if our friends in the meter business would give us a meter clock, where the holes in the plates were bushed with something which would not corrode, a good many water works superintendents would rise up and call them blessed. [Laughter.] If you would go around and see the places where meters are set and the usage that they get, I think you would actually wonder sometimes that they did not stop from mere disgust at their surroundings. [Laughter.] But, as Mr. Tilden has well said, the modern water meter is a marvel of mechanical ingenuity and accuracy, and I think that any one who has to do with a large number of them will say that it would be hard to find a corresponding number of appliances, so intricately constructed as they are and put to such hard service as they are put to, that would do as well. [Applause.]

Mr. George H. Snell.* Mr. President, I have been very much pleased with this discussion and with Mr. French's paper, although I could not hear every thing that he said. All of our services in Attleboro are metered, and I sometimes think we know something about meters. From investigations we have made as to the effect of the vibration of the pump it seems to me impossible that a meter can turn without a discharge. There must be water going through in order to make a registration.

I remember a case about two years ago where a man who was a plumber and who used to repair our meters and thought he knew all about them, came and said he had a meter which certainly registered from the vibration of the pump. We went into his cellar and watched the meter for probably half an hour, and we found that it was registering; I think it registered some 10 feet during that time, possibly not so much as that. I said "There is a leak somewhere," but he thought it impossible. As the pipe ran underneath the concrete cellar bottom I suggested shutting it off, as there was a shut-off in front of the meter before the pipe passed

* Superintendent of Water Works, Attleboro, Mass.

under the concrete, and we found when it was shut off the meter did not register although we had the same vibration. What he did was to cut off his pipe underneath and piped overhead and in that way remedied the whole trouble.

The gentleman who first spoke referred to a locomotive running away; but it could not run away if the exhaust was stopped up; it would be impossible. The exhaust must be open to enable the engine to make a revolution. I believe those things should be considered as there is always some foreign trouble which we do not understand.

In regard to registration, we do most of our repairing; we have a good testing bench and a man who works continually on meters, and we find that most of the trouble is on the inside, either a little sediment, rust or some foreign substance, that stops the piston or the disc, as the case may be. Very seldom does the register bother us. My experience has been that while meters may run and register, they should be taken care of and cleaned out and repaired once in two or three years.

I saw one in Fall River a few years ago, which the man in charge of the meters had taken out and brought in, and there was really nothing left of it on the inside. He said the meter had been in for eighteen years, and I said, "How long do you think it has been registering?"

"I don't think it has registered," he said, "in the last ten years." [Laughter.]

I believe the main dependence of the water department, if you have a metered system, must be on the maintenance of your meters. In one city I know of, but which I will not name because I may not be able to state the facts just exactly as they were, they used to have a per capita consumption of 220 gallons per day. They investigated with the idea of increasing their water supply and employed an engineer who took the matter up, made an estimate of what the waste was, and as a result of the investigation they put in meters at an expense of about $35 000, and brought the per capita consumption down to somewhere in the vicinity of 85 gallons. The meters were set and no one knew anything about maintaining them or taking care of them, and in four years they had done nothing to the meters in the way of re-

pairing them, had not even taken them out when stopped, and as a result got back to 200 gallons per capita per day.

Now the only way to get income from the department, according to my idea, is to maintain the meters properly. Personally the only office work I do, outside of the correspondence and taking care of the necessary business, is making out the semi-annual bills. I charge on the ledger and the clerks in the office make the bills, and by being familiar with the charges, knowing the people and also the conditions, if the consumption is not as much as in previous months I invariably find the trouble. For instance, if they have been using $100 worth of water and it falls down to $65 worth, I notice from the meter readings that it has dropped from 15 000 to 12 000, 10 000, 8 000, 5 000, or 2 000, and that shows it is time the meter was taken out and changed.

I believe there should be some one at the head of every department who should be familiar with these conditions. We have 1 800 meters but, if there were 5 000 or more, there should be some one, even if it has to be divided into different sections, who will be responsible for each section and who will know the conditions.

In regard to connections where hot water is liable to back up to the meter, we had such a case in South Attleboro, — Sadler Brothers. They had a meter and paid about $25 or $26 each six months. When I came to the office it seemed to me that was a very small amount for boiler use and for a jewelry shop, and I inquired into it, and they said every time they read the meter it had stopped, so they simply got readings of a few hundred feet and made an average from that. After investigation we put in a check valve at our own expense and in the next six months we got $105. We kept along at $105, $115, $120 each six months, but later it stopped again, when a second check was put in with a valve between the two, so we could clean them, as sediment would get in them and let the water back. In that way we got $225 to $230 each year against probably $50 or $55 formerly.

Mr. John C. Whitney.* Nearly all of us must have had experiences in regard to meters registering when apparently no water was passing through, similar to those related by Mr. French. I

* Water Commissioner, Newton, Mass.

remember distinctly my first experience in that line. The complainant was a member of the water board. He came into the office and said that his meter was registering when no water was being drawn, and he knew it. Of course we received his complaint with polite incredulity, but offered to investigate the matter, and I was sent up to the house to make the investigation. The gentleman said he had to be away for a while and the family was not at home, but here was the meter and there was the plumbing system and I could make any investigation I chose and see what could be found. I went through the house and everything was tight, nothing running, not even a drop. I watched the meter and in the course of a few moments it moved up a tenth of a foot. I made another trip about the house to make sure that there wasn't something running, but no sign of trouble anywhere, and in the meantime the meter had moved ahead a tenth more. There was a shut-off on the pipe line within, possibly, 15 feet of the meter. I shut that off, made sure it was tight, that the water wasn't leaking by and watched the meter and in about five minutes it moved up another tenth. I found it was recording at the rate of about a foot and a half an hour.

The meter was one in which the registering mechanism can only move in one direction, of the ratchet-gear type, and was situated within half a mile of the pumping station on very high ground. The service pipe supplying the house was, I should think, 200 or 300 feet in length, and the pressure in the cellar probably not more than 10 or 12 pounds. There was no question whatever but this meter was working on pump pulsations. There was no air cushion and no way I could see by which the water could be forced through the meter and register, but it was doing it. We substituted for that meter one of a type which could record the reaction as well as the action, and after that there was no trouble.

Mr. John H. Flynn.* We have heard about what funny things meters are, but nobody has said anything yet about the men who read the meters. A friend of mine came to see me within six weeks and he said, " How much ought I to pay the city of Boston for what water I use? " I said, " How many rooms are you occupying? " He told me he was occupying three rooms in a

* Boston Water Department.

building. "How many fixtures have you got?" "Well, I have got a water closet and a sink." "Do you use water for any mechanical purpose?" "No, only for washing hands once in a while." I said, "I should judge somewhere about $7 or $8 a year would be fair." He said, "Well, I should judge that would be about fair; but how would $140 a year strike you?" I said, "That would be a little too high." He said, "I have got a private meter on the pipe I use, and for three quarters now I have paid $35 each quarter. Now, will you be kind enough to look at that meter for me?" I told him I would the first time I had any leisure; and as we are very busy in the water department, as you know, I had to wait a little before I could get a chance to go up and look at the meter. It seemed to be all right, and according to the way I read it he had used 27 cents' worth. I asked him who read the meter, and he said the janitor of the building. I asked him who made out the bills, and he said the janitor did. I asked him if he would be kind enough to let me see them, and he showed me the bills, each dated the first of the month ending the quarter, and I found that they all read just alike, that the number of feet he had used was just the same in every case, and it figured out that there was $35 for him to pay. So I saw the janitor and asked him who taught him to read meters. He said he learned how to do it from a book. [Laughter.] I said to him, "How do you make it that exactly the same amount of water is used every quarter?" He says, "Well, I always find the hands in about the same place." [Laughter.] Said I, "In other words, you think that the hands make a complete revolution?" "That is it," he says, "that is the only way it could happen." I took the meter out and tested it and I found that the meter was off only 500 per cent. in favor of the consumer. [Laughter.] The trouble simply was, that the gears had got twisted around in such a way that they didn't mesh very well and the meter would run along without turning the hands at all. I notified through him the manufacturers of the meter and they very kindly took it out. I haven't seen him since, but I guess he hasn't been paying quite so much as he used to.

MR. FRANK L. NORTHROP.* We had a funny experience once with a man who ran a bottling establishment. According to the

*Mechanical Engineer, Union Water Meter Co., Boston, Mass.

meter we owed him every month about \$25. They were using water night and day all the time, there was a stable back of the building, and he had a great many fixtures in the building. We found that his system was all connected through the building. He had one $\frac{3}{4}$-inch and two 2-inch meters. After a while we found that the pipe going to the stable had a leak into a blind sewer, which no one could see, and the two 2-inch meters were furnishing water for the building and also for the sewer backward through the $\frac{3}{4}$-inch meter.

Mr. J. C. Hammond, Jr. I think, Mr. President, that if you should find our meeting dragging a little later, it would be a good plan for you to ask our meter friends to tell us who makes the best meter. If anybody asks me who has the best wife in my town I can tell him right off, but if anybody asks me who makes the best meter I confess that I am up against it. There are lots of good meters and some poor ones, but I had rather have a poor one than none. They are good scarers. [Laughter.] A red flag won't keep a man from being run over if he persists in standing on the railroad track, but if he has any brains he will keep off the track when he sees the red flag; I had rather have a tomato can and a dollar watch on a supply pipe than not have anything. [Laughter.]

EXPERIENCE WITH "UNIVERSAL" CAST-IRON PIPE.

TOPICAL DISCUSSION.

[*February 13, 1907.*]

President Whitney announced that an inquiry had been received from a member of the Association, who was unable to be present, asking for some information in regard to "Universal" pipe, and invited any one who had had experience with it to state the results that had been obtained.

Mr. John H. Cook. The Passaic Water Company of Paterson, N. J., has laid two lines of this pipe, 12 inches in diameter, across the Passaic River a mile or two above the town, and we have found it satisfactory. The reason we bought it was because it was convenient to lay under water. The pipe is made with a ground joint, the lengths are fastened together with bolts and lugs, and the pipe can be laid with unskilled labor. As a matter of fact, this line of pipe was laid by divers in a trench which was dug across the river under 6 or 8 feet of water in some places, and they could put it together very conveniently by means of the bolts and lugs. When the line was tested it was found to be tight and it has remained tight up to the present time.

At Little Falls, N. J., five or six miles up the river above Paterson, two or three miles of this pipe was laid by Mr. A. W. Cuddeback, a member of this Association, about two years ago, and I think he has found it satisfactory. It is a pipe which may be laid very rapidly by men who are not particularly skillful. I remember seeing up there one day a piece of trench which I should say was 250 feet long, and that length of 6-inch pipe was laid by two Italian laborers that day, and when tested it proved to be reasonably tight. I think they had to do some little adjusting afterwards, but not much.

The makers claim that the pipe may be laid considerably out of line without leaking, and that it may move or settle somewhat in the trench without leaking. I believe this pipe was bought at

Little Falls not because they preferred it, because it was a new thing then, but because they could get it very promptly, and the people who were putting it on the market were very anxious that more of this pipe should be laid.

The President. Is lead used in the joints?

Mr. Cook. No; no lead is used in the joints at all. They are ground joints. There is a male and female joint, and they are just put together and bolts fasten the pipe together by means of lugs which are on the side of the pipe. We laid two lines of 12-inch pipe across the river, and the pipe at Little Falls I think ranged from 12 inches down to 4 inches.

The President. And that was also under a light head?

Mr. Cook. No; the Little Falls pipe, I think, was at one time, indeed, has at different times, been under quite heavy pressure, because we drop the pressure through a regulator, or through a pressure-reducing valve, to this Little Falls line, but I think once or twice the reducing valve got out of order and put the total pressure on the pipes, and I think at that time they had no trouble with it to speak of. The Little Falls pipe system is now under a pressure of about 100 pounds, that is the pressure at the water company's office on the main street of the village. I think they have had one or two leaks, but no more than I should expect in any system.

A Member. How long are the lengths of pipe?

Mr. Cook. The lengths are short. As I remember, they are about 6 feet. Anyway, it comes in short lengths, and of course they have specials of different kinds which are contrived for this pipe.

A Member. How does it compare in cost?

Mr. Cook. It is much lighter, it does not weigh as much as ordinary cast-iron pipe, but the makers claim they use a much higher grade of iron. I don't know about that, however.

Mr. Coggeshall. Will it take the place of flexible-joint pipe?

Mr. Cook. The makers claim it will, and it seems to be very satisfactory. As we laid it across the river, of course it was more or less out of line, and it was laid under the water by divers.

A Member. What is the remedy for leaky joints?

Mr. Cook. I suppose it would be to dig up the pipe and tighten up all the bolts. I have had no experience beyond what I tell you.

A Member. As I understand it, the pipe you laid across the river was under about 6 feet head of water in the river?

Mr. Cook. Yes.

A Member. What pressure did you have on the pipe?

Mr. Cook. I think the pressure was 30 or 40 pounds, but the Little Falls pipe system was under considerably heavier pressure than that.

Mr. Charles W. Sherman. I remember that a few months ago some one, I think it was a member of the Association, told me of a case where he had used the Universal pipe across a marsh for a distance, as I remember it, of about half a mile. I can't remember who it was who told me, or where the place was, but he said he had found it entirely successful. It was easy to lay, and it obviated the trouble he would have had if he had tried to make lead joints in that wet locality.

The difficulty, if any, with this pipe, seems to me to be in the durability of the bolts. As I remember it, there are two bolts which draw the lengths together and make the joint, and so far as I know none of this pipe has yet been in service long enough to give any reliable data as to the life of these bolts. I should be somewhat afraid that after a few years this pipe, laid in a trench, would develop leaks which would be pretty hard to locate, especially with a joint every six feet. Of course they claim that if the joints are once drawn up tight and the earth thoroughly backfilled around the pipe, it is going to stay there and remain tight. I don't know how far I should want to trust that to be the case after the bolts were gone.

There is no reason, so far as I can see, why the joint should not be as tight when the pipe is new as in any pipe, and why the pipe itself should not be as durable as any pipe.

Answering Mr. Coggeshall's inquiry as to its taking the place of flexible pipe, I do not think it would take the place of a spherical jointed pipe which would be used, for instance, in laying a submerged pipe line from a scow, allowing it to sink as the pipe is jointed and thrown out. It would allow no such flexibility of joint as that,

but it does not have to be laid strictly to line and grade, as some of the ground joints of bell and spigot pipe would have to be. I would suppose that the deflection available in the pipe would be about the same as in the ordinary bell and spigot joint pipe.

The President. I should like to ask Mr. Conard if he has ever had any experience with this pipe. .

Mr. William R. Conard. I have never had any direct experience with the pipe. I have seen it in one or two places, not in service, but where it has been exhibited and demonstrated for exhibition purposes more or less. I will say that it is cast horizontally rather than vertically, in 6-foot lengths. The finished portion, I think, of the male end is about an inch to an inch and a quarter in length, beveled, and the female end is not quite so long, possibly three quarters to an inch. After the bolts are drawn tight, there isn't much room for flexibility, and I should imagine when dampness got into the joint it would rust it up and make practically a solid line of pipe. What will happen after the bolts rust through, or what will happen when expansion and contraction comes on the line, is something I should judge the pipe has not been in service long enough to demonstrate fully yet. There was quite a line of it laid in Atlantic City, a year or two ago, for, I think, the Atlantic City Gas Company, all the way from 4-inch to 16-inch. I know some of it was as large as 12-inch, and I think there was some as large as 16-inch.

SOME OBSERVATIONS ON CAST–IRON PIPE SPECIFICATIONS.

BY WILLIAM R. CONARD, BURLINGTON, N. J.

[*Read February 13, 1907.*]

It may be well for me in beginning this paper to call your attention anew to a portion of the report of the Committee on Standard Specifications for Cast-Iron Pipe, presented December 11, 1901, which is as follows:

"The committee has conceived its duty to be not the recommendation of new processes, radical changes in existing specifications, nor even an unvarying list of weights for different heads or pressures, but rather a codification of the best present practice in design and manufacture in such form that, if used as a standard, pipe can be furnished by the manufacturers, and procured by purchasers, with more certainty and satisfaction than can be done at present, even with the most perfect individual specifications, and at the same time to be sufficiently elastic to allow, with a minimum of trouble, the incorporation of special ideas in an order for pipes.

"It is believed that standard specifications, to obtain general acceptance, must allow for the personal equation of the user. While the many difficulties attending the present individualistic methods are well known, the committee recognizes the futility of the adoption of a standard which, although securing uniformity, too closely limits individual freedom of practice.

"The variation in form and dimensions of pipes and castings from different foundries, and even in different lots from the same foundry, causes much trouble and expense in pipe laying. Special castings are the most troublesome in this respect, spigots often being too large or thick to allow sufficient lead room in the bell of the pipe, even if they will enter at all without chipping the bead. Different classes of pipe often cause trouble in the same way, especially when the different thickness of shell is secured by a change in the outside diameter.

"Unless drawings are furnished for special castings (which it is not always practicable to do, especially for small orders) one does not know the length or weight, or even if the castings will

come with bell and spigot, or bells all around. Sometimes reducers are sent with bells on the large end and sometimes on the small end. The radii of bends can rarely be ascertained in advance.

"Even when drawings are furnished, unless an inspector is at the works, the castings are quite as likely to come of some other pattern and weight (not usually lighter), when the alternatives are to use those sent or wait for others to be cast and delivered.

"On the other hand, it is clearly impossible for the manufacturer to keep a stock of pipe or specials on hand, when he cannot be sure that any two orders will have the same requirements, even in the simplest detail.

"The entire lack of system in fixing the weights of pipes is the cause of much trouble and perplexity, the weight cards of the different foundries agreeing no better than the tables of different engineers. The great variety in specifications not only causes trouble in the foundry, but results to the purchaser of pipe not inspected at the works and of pipe in small lots or on quick orders, in the receipt of pipe which, although it may make fairly good work when laid, is nothing more nor less than a job lot of different sorts and sizes, very difficult to lay."

Now let us consider the circumstances which inspired this portion of and intent of the committee and report.

Just as stated, the weight cards of the foundries varied as much as the engineers' tables, and often the results obtained by the foundries themselves varied considerably from their own weight cards; and for a number of years the cry of the foundries was that the engineer's ideas as to the dimensions of the pipe for a given service and the forms, not only of his specials, but of the bells and spigots of his pipe, varied so from that of his brother engineer that the foundryman didn't know how to provide patterns, etc., to meet the demand; in other words, he didn't know "where he was at." This was, to a large extent, true, and and it is indeed gratifying to pipe purchasers generally, and must be quite satisfying to your committee, to note how generally the engineers have been willing to either wholly or in part drop their individual ideas and standards and adapt themselves to the New England Specifications.

Observations of the extent to which the various classes of pipe have been used by those taking the New England Specifications as their standard, indicate that —

On 4-in., 6-in., and 8-in., classes E and G have been most used;
10-in., 12-in., and 16-in., classes D, E, and F have been most used;
20-in. and 24-in., classes C, D, and E have been most used;
30-in. and 36-in., classes C, D, E, and F have been most used;
48-in. and 60-in., classes C, D, and E have been most used;

with a tendency toward heavier pipe — this tendency being due to the higher pressures demanded and to the increase in street traffic, both in bulk and, naturally, in weight. Where the lighter classes of pipe have been employed it has been mostly for connections in existing work, and on account of the advances in cost of pipe, where it has been necessary to get the greatest length of pipe for the least money, within reasonable safety for the use intended.

The enormous demand for cast-iron pipe, as well as other materials, during the last few years, and the consequent inability of the purchaser to get deliveries unless he were willing to take such pipe, both in dimensions and in quality, as the manufacturer would furnish, makes it difficult to arrive at a very close estimate of the proportionate quantities of pipe bought under the New England Water Works Association specifications, and under other or no specifications, but to speak roughly I estimate that about 33 per cent. of the cities of 30 000 and over in the New England and Middle Atlantic states are endeavoring to use the New England Water Works specifications; about 13 per cent. still use their own specifications; the balance I am uncertain about, but the difficulty of getting pipe during the last few years has had a somewhat deterrent effect, and probably many who would have liked to use the New England Specifications, have had to take what they could get or go without. Outside of the territory mentioned, not more than probably 15 per cent. are using New England Specifications, several still using their own, the balance accepting whatever they can get.

However, consulting and constructing engineers who have extended existing works or put in new have, almost to a man, used New England Specifications so far as the New England States are concerned. Outside New England comparatively few have used them, although some have.

The Committee on Standard Specifications of this Association has been revived for the purpose, as I understand it, of conferring

with the committee of the American Water Works Association, and also, if found advisable, of recommending changes in the New England Specifications when experience with their use shows that a change is needed. To me it seems appropriate that we ask ourselves the question; Has not the time about arrived when we should consider the advisability of some changes in the specifications?

Experience has shown that only about four classes, and they the middle classes, have been very generally used.

While to maintain one outside diameter and vary the weights or classes by increasing or decreasing the internal diameter would theoretically be a thing that would suit nearly all parties interested, both purchaser and manufacturer, it cannot be done successfully in actual foundry practice; for while a mechanism can be laid out on paper that would do the trick to a nicety, a mechanism to vary the cores for the different classes involves the making of a machine of various and very accurate adjustments, and as the average coremaker is not an expert machinist, he would not realize the importance of having the adjustments and cores just so, while the very nature of the material used in coremaking would militate against close adjustments on such a machine; or else it involves the making of a different core board for each of the variations of a given nominal diameter and, in turn, the making of various fixtures to take the different sized cores; all of which is not only expensive to get up, but also hard to keep track of and not get them mixed, which in turn would necessitate an additional force of fixture men, and therefore an increased cost of production, and consequent increase of cost to the purchaser.

While the New England Specifications do not confine themselves to one outside diameter for all classes, they do give several classes to each specified outside diameter, which calls for the increasing or decreasing of the internal diameter; and therefore the same difficulty in manufacture is experienced as there would be in trying to use only one outside diameter.

Now, as noted earlier in this article, there have been certain classes that have been quite generally used by those purchasing under New England Specifications; would it not be possible to eliminate a number of the classes of the various sizes and so

readjust those left that the requirements for foundry fixtures will be simplified, and the manufacturer can obtain the desired weights and thicknesses with such fixtures as have been found practical?

By this I mean that by having fewer classes, and so arranging their variations that, say, four sets of cores and allied fixtures could be gotten out by the foundries to cover the pipe that would ordinarily be used, a basis would be reached that would probably be satisfactory to all. Generally speaking, the foundries have fixtures on hand that could be readily adjusted to two outside diameters, though if a reduction in number of classes was made, the specified outside diameters might need some rearranging to meet the services they would cover.

One thing the specifications are silent on is, in that portion relating to hydrostatic test, about the length of time the pressure shall remain on the pipe. Experience has shown quite conclusively that with the ordinary method of testing and the length of time which the pressure remains on, the test does not develop defects in the walls of the pipe unless they are such that the pipe bursts; for the present method is to throw the hydraulic pressure on quickly and off quickly, and the only function it performs is that of water hammer. On the smaller sizes, and the light classes of the larger sizes where the thickness of the wall is such that defects cannot hide themselves so well, this, while not desirable, in a manner answers; but on the larger sizes of the medium and heavier classes it often takes from three to five, and even ten minutes, to allow the water to force its way through any porous places, and unless there is an inspector on hand to see that the pressure is maintained for a proper length of time, it is not always done, as the facilities of the testing departments of the foundries have not been arranged to keep pace with the largely increased output. For example, there is a foundry which is turning out about 500 lengths of 4-inch to 6-inch pipe per day, with only one piece of testing apparatus to take care of this output. Their working day is about nine and one-half hours, so that it doesn't take much figuring to see that there cannot be much time spent on testing each pipe if the entire lot is to be hydraulically tested.

Therefore, it would seem as though some requirement should be inserted that the hydraulic pressure be maintained on pipe of 4-inch to 14-inch diameter say two minutes, 16-inch to 24-inch say three minutes, 30-inch to 42-inch say five minutes, and 48 inch and over ten minutes, or such time as your committee may think best.

Another matter not covered by pipe specifications, generally, is the hydrostatic testing of special castings. It has not been required largely because of the variations in forms and dimensions, but it would seem to me fully as important as the testing of straight pipe, and would develop not only weaknesses in the way of defects of the iron, but possible defects in design; and apparatus can be arranged for making these tests.

The subject is a broad one and admits of many arguments and requires careful thought. It could be extended much further, going into details of the actual use of pipe, etc., but that is out of my line and should be covered by those who are using the pipe.

DISCUSSION.

President Whitney. The paper is now open for discussion. I think we should like to hear from Mr. McInnes, of Boston, who had great experience with pipes and castings.

Mr. Frank A. McInnes.* I should like to ask Mr. Conard one question, and that is whether he thinks there could not be to advantage a change in our present test requirement for the strength of iron, which is that a bar 2 feet long, 2 inches wide, and 1 inch thick shall sustain a load of 1 900 pounds and shall show a deflection of not less than .3 of an inch. I recall cases where the deflection at 1 900 pounds would be about .25 or .26, and yet that iron would break up to perhaps 2 600 pounds with a total deflection of .35, entirely too hard to satisfactorily admit of drilling and cutting. It has always seemed to me it would be better to say that at 1 900 pounds the deflection shall be not less than a certain amount; in other words, is it practicable to limit the deflection at a certain loading without serious injustice to the foundry, and in that way eliminate the possibility of getting very hard iron?

* Assistant City Engineer, Boston, Mass.

Mr. Conard. I should say, yes. On a number of tests that were made some years ago for the Metropolitan Water and Sewerage Board, a series extending over a matter of possibly ten months or a year, my recollection of the deflections is that at 1 900 pounds the deflection was about .24, .25, or .26 inch, with a further deflection at 2 100 pounds of about 4 or 5 points further, and the deflection advanced with the strength of the iron in just about that ratio, about .05 of an inch for every 200 pounds of pressure brought to bear on the bar from 1 700 pounds up. Below that I have taken no records.

The President. I wonder if Mr. Foss could give us any points in regard to the tests of metal referred to by Mr. Conard?

Mr. William E. Foss.* I am not familiar with the results of those tests, so cannot state intelligently anything about them.

The President. How much experience have you had with these standard pipe specifications, Mr. Foss?

Mr. Foss. Very little. Most of our pipe laying was completed before the standard specifications were adopted, but during several years on this work I had considerable experience in laying pipes cast under the Metropolitan Water Works specifications then in force. There are two points that I had thought of on which I should like to hear from Mr. Conard. He has already mentioned one of them, that is the testing of special castings. It always seemed to me that it was much more important to test the special castings than it was to test the straight pipes, but I had not understood before just why the specials were not tested. The other point I should like to ask about is in regard to the special curves for 48-inch and 60-inch pipe lines. I have found in laying pipe lines with these curves of large diameter that the curves throw an angle less than is specified. It is always that way; the deflection obtained is less than the specified angle of the curve used. I suppose there is a reason for it, and perhaps Mr. Conard can tell us what it is.

Mr. Conard. I don't know as I quite understand just what you mean. You mean there is a difference that does not show in the design of the special between the short side and the long side of the curve?

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* Division Engineer, Metropolitan Water Works, Boston, Mass.

Mr. Foss. Yes. For instance, a 45-degree curve, instead of throwing 45 degrees, will throw about 44 or 44½ degrees; and a $\frac{1}{16}$ curve will throw 22 degrees or perhaps as low as 21 degrees, or even less, instead of the specified 22 degrees 30 minutes.

Mr. Conard. Don't you find it works the other way too, at times?

Mr. Foss. No. All my experience has been that the special throws less than the specified angle.

Mr. Conard. My experience with specials is that the length will vary somewhat. Testing them with a templet I find variations; some of them come short, some of them come longer than called for, and the only solution I could ever get of it is that it is due to shrinkage, that there will be variations in the shrinkage of the iron. I have also found that where a casting was carefully built up, the mold built just to length, making allowance for this shrinkage, on the short side it might come less than the requirement and on the long side be long, therefore throwing the angle out somewhat. Then I have found it where both sides would be long, and I have also found it where the shortest side was a bit long and the long side a little short. The only reason I could ever give for that was the shrinkage was not always quite equal in the cooling of the casting. If you will just remind me what your first question was, I should like to answer that.

Mr. Foss. That one regarding testing of specials; I think you did answer in a measure in your paper.

Mr. Conard. It would seem very important that specials should be tested. One reason why it has not been done is because of the difficulty of getting up apparatus which would do the work satisfactorily at the foundry. That, I guess, is the real reason why it has not been done heretofore. But it would seem to be a good thing, and a very important thing. I have in mind a 48- by 36-inch tee, which I was looking at some years ago, which was defective, as I claimed. The foundry took exception to the matter and it was carried along for some time. Finally the casting was shipped to the point of destination and I was afterward called over, before the casting was used, and after a conference the casting was broken and it was very clearly demonstrated that the

casting was not only defective, but very defective. If an arrangement could have been made to have subjected that casting to a pressure test at the foundry it would have very clearly demonstrated there and then that it was a defective casting, and it would have saved a lot of worry and trouble.

Mr. Foss. There is one other point which possibly Mr. Conard can give us some information on, and that is the coating of pipes on the outside. I don't know what the foundry practice is, but I imagine from what I have seen of pipes that have been exposed to gases and electrolysis that after the pipe is coated it must be rolled out on skids while still damp, before the coating has thoroughly hardened; as I find that rusting and disintegration of the iron take place in rings about 2½ feet from the bell and spigot ends. It would be very desirable to have that avoided.

Mr. Conard. That is another case where the foundries have not quite kept up with their output in handling the pipes for coating. The output at the present time of the pipe foundries is such that it would simply be impossible for them to take a pipe and coat it and lay it in a position where it might remain inert until the coating had hardened so that there would be no breaking of the surface after it was cooled. It is true that as a rule they are placed on skids and turned over, or partially turned over every few minutes until they reach the point of weighing and testing. That is done for two reasons. One reason is to allow the flow of the coating to become equal all over the pipe, as the pipe and coating are both hot when the pipes are dipped, and naturally the coating stays somewhat fluid until cool; and the other, of course, is to make room for pipe which are being coated afterwards.

Mr. John Doyle.* I think I can agree with what the gentleman on my left [Mr. Foss] says with regard to the variation of specials. My experience has been in laying 40-inch pipe and 30-inch pipe on a 50-foot radius, the trench having been laid out by a competent engineer, that I could not make both ends meet, and it has been necessary for me to make the trench fit the pipe. I have found quite a difference between the long end and the short end of the curved pieces, and I have found that in a great many instances.

* Boston Water Works, Boston, Mass.

Mr. Frank L. Fuller.* I think this testing of special castings is a very important matter, and am glad it has been brought up. In a water works job this last season, with 7 or 8 miles of pipe, there were at least 4 specials that proved defective. I don't know how many others there were, because, in many cases, we had to do the back-filling before the pipes were tested. In one case, where it was necessary to cross a river on a special bridge, two out of four $\frac{1}{8}$ bends, which had come late in the season and which we needed at once, were defective, and we were obliged to wait three or four weeks to get new ones; and one of these was defective. We calked it up the best we could and let it go. I suggested to the foundry that it would be a good thing to test their specials, but they said they made so many they could not do it. It seemed to me that the more they made the more necessity there was of testing them.

Now it is very annoying to get a line of pipe laid and turn on the water and find that some of the specials leak. It means a long delay in getting new ones. If you have a leaky straight pipe you generally have pipe enough on hand to replace it and you get over your difficulty at once; but if you have a leaky special and have to wait three or four weeks to get a new one, it is a serious affair. I think the towns and cities would be willing to pay enough more for their specials to have them tested, and I think it would be a great satisfaction to know that the castings we are using had actually been tested and were perfect.

Mr. Conard. The question has been asked, Why cannot the hydraulic test be made on specials handily by using a ball or knuckle joint on the angle end of a special? There could be apparatus arranged for testing specials, but it would be quite expensive, though I saw a wrinkle only a few weeks ago at the Pennsylvania Steel Casting Company's works at Chester, Pa., which appealed to me quite strongly for the testing of special castings. The folks there had arranged a large circular frame with four moving heads operated by hydraulic power, and by that method they were able to clasp almost anything, of almost any shape, and subject it to hydraulic pressure. It seemed to me if this question of testing specials were only taken up and

* Civil Engineer, Boston, Mass.

insisted on (made a portion of the specifications), the manufacturer would be willing to put in some such apparatus, and I think that an apparatus of that character could be made to work quite satisfactorily.

THE PRESIDENT. I think we should hear something from the foundrymen's end of this subject, and I will call on Mr. Walter Wood for a few remarks.

MR. WALTER WOOD.* It was exceedingly interesting to me to hear the opening suggestions of the paper about what we used to run up against in the olden times. Every engineer used to send in a different pattern, not only for the internal diameter of his pipe, but also patterns for an infinite variety of special castings. I am glad that this old history has been touched on, because it is a source of great annoyance as the pipes are being laid, and it is often and naturally thrown up at the manufacturer that he was making things of every kind, when as matter of fact he was compelled to do so on account of the variety of orders which came in and to which he had to adapt himself.

It is fortunate, however, that the discussion about standards has gone so far that a large part of that irregularity has been eliminated from the burdens that have been thrown upon the foundryman. He is only too ready to adjust himself to any lines that can be worked on regularly, and it will be a comfort to him, and a great comfort to the people in the pipe trench, if steps in that direction are well taken, and they will always have the foundryman's strong and active support. It will take a little while to thresh the matter out. Our pattern loft is filled with all sorts of designs, and some people will still have specials or goods made from those designs. But time will settle all that, and when we get the subject of standard specifications finally worked out the trouble will be a thing of history.

There is one thing that I am sorry occurred about forty years ago. It is well known in New England in connection with the Salem water works. Perhaps none of us are quite old enough to recollect all the occurrence, but it has gone into history, and we are more or less familiar with it.

I refer to it merely to lead up to this one fact, that so far as I

* Of R. D. Wood & Co., Philadelphia, Pa.

have any knowledge of cast-iron pipe foundries, there is absolutely no attempt on their part to do otherwise than to follow the wishes of their customers. I think they all wish to do thoroughly good work, and all wish to fall in with ideas that are put before them, although sometimes making practical suggestions regarding them; but there is no thought on the part of any of the founders whom I know of any antagonism or difference of interest — that is the best word to use — between the persons who buy and the persons who make. Our interests are all one, and I think anything which is taken hold of by the users of pipe which will benefit the manufacture and the furnishing of it, will be met with that spirit on the part of the manufacturers.

The specifications which were originally adopted by the New England Water Works Association, and which were so widely spread and so widely used, have naturally come under more or less discussion, and particularly on one point, which was alluded to in the paper just read and I think very properly so; that is, the large number of classes in the specifications. The discussion which has taken place on the subject of classes has largely brought itself down to this: If you will take the two extremes of weight which are generally used in pipes, you will find that about four classes will cover this range of weights, so that each class will not be more than the allowed variation from the other. Of course I am speaking approximately. In other words, there is an allowance of 8 per cent., four up and four down, and there are four classes, and that is 32 per cent. That will largely cover all the variation of weights between the high weights and the low weights, and, therefore, a more careful investigation of the subject of classes has led those who have followed the New England movement to come to four classes.

The gentleman who read the paper very properly alluded to the question of the making of cores, and whether the variation of weights could be made through the variation of the cores or through the variation of outside diameters. If that question is carefully looked into with the drawings before you, you will find that four classes can be reached with the use of two patterns of outside diameter, and one variation of the core for each; this will make the four classes. You will, therefore, only have one variation

of outside diameter and one variation of core, which will simplify the question very much with the manufacturers; and while it is not exactly the best theoretical way of meeting the question, yet it is probably the best solution between practice and theory. In this way the matter of classification readily adjusts itself.

There was a suggestion in the paper that the manufacturers had a specification of their own. Perhaps in ordinary parlance there is some basis for alluding to it in that way. But, to put it a little more accurately, it is this way: The American Society for Testing Materials appointed a committee which, in considering the specifications, worked out the four classes I have alluded to, and also made some other changes, not very prominent ones, in the New England specifications. That society's specifications have now been before the country for some little time, and perhaps have been more used by the foundrymen in their own practice than the New England specifications, and hence they may have come to be called the foundrymen's specifications. But they are *not* the foundrymen's specifications; the fact is merely that when two specifications are laid before the foundryman he naturally chooses that which is the simplest, easiest, and cheapest to manufacture under. There is really very little difference between the two, and it is chiefly in the subject of classification which we have been speaking about.

It would be very well if specifications could be uniform not only in this country, but, for those of us who are on the seaboard, in foreign countries also. It is a matter of some pride with us in America to have foreign trade, and uniform specifications would very largely help. So perhaps that has been a factor in the foundryman's thoughts in working under the Society for Testing Materials' specifications, viz., the idea of working towards an international standard.

I only speak of this question of the foundrymen's specifications because I want to get it clearly before our friend's mind that there is no antagonism to the specifications adopted by the New England engineers.

There is one other thing in connection with international specifications which will naturally come up, and it is a very excellent one for the buyer to think seriously about. It is im-

possible to make a casting 13½ feet long without the upper end being more or less porous. Abroad their custom is to cut off that end for 3 or 4 or 5 inches, and in that way they get a much more perfect pipe than is called for by our American specifications. In our large-diameter pipes we have in our foundry adopted the principle very largely, though not in every case, of cutting off the ends of the pipe so as to secure a clean spigot. As it is an added expense, we haven't done it in every case, but the tendency of our manufacture is towards cutting off the upper end of every pipe in order to get a perfect spigot, which is a very desirable thing, because the bead is the weakest part of the pipe, and it is a constant trouble to the inspectors to know whether they should pass a pipe with 1 hole or 3 holes or a dozen holes in the spigot, and it is a constant source of worry and loss to the consumer and to the manufacturer until the point is settled. Had we better not adopt in this country the principle of cutting off that portion of the pipe which is always more or less porous and always giving trouble to everybody and is a source of constant friction? I suppose if we ever reach an international specification that will be one clause which every foreign engineer will insist shall be inserted, viz., to make a pipe perfect by cutting off the part of the pipe which is always more or less bad. Whether or not the time has come for doing that in this country is for the persons who buy pipe to settle. It will not add very much to the expense, and will certainly give them what we all aim for, that is, more perfect castings.

There is another matter which I may speak of as a matter of curiosity, although I think both the English engineers and the American engineers will be slow to adopt it. The best foreign practice is to have no bead on the end of the pipe. I think there is too much conservatism among our engineers, however, to do away with the bead offhand, and I only speak of it as an advance in the manufacture of pipe which has been largely adopted abroad, but which I am afraid our conservatism will keep us from promptly adopting here.

The function of the bead after all is not to strengthen the end of the pipe, because the slight ring of cast iron which constitutes the bead is too small a piece of metal to strengthen materially the end of the pipe. A 6-inch pipe weighs over 300 pounds, and a

12-inch pipe weighs 1 000 pounds, and no little ring of iron like a bead will furnish strength to stand the dropping of the pipe on its end. The bead adds so little strength to the end of the pipe that I don't know why it was put there originally, unless it was for the sake of helping to center the pipe as it goes in the socket, so the man in calking won't have the barrel of the pipe lying on the bottom of the socket. That is to my mind the real function of the bead, — that it tends to help the calking.

Now the way that is secured in the pipe that has no bead is to have a slight taper at the bottom of the socket, so that when the pipe is driven home the end of the pipe centers itself on the taper, and the full calking room is at once obtained, instead of the calking room which the bead gives, which is only the height of the bead and which is not the full calking room. So really a beadless pipe centers rather more accurately and rather more thoroughly than a pipe with a bead.

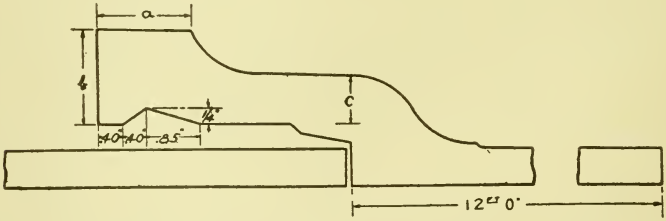


FIG. 1. JOINT IN CAST-IRON PIPE WITHOUT BEAD ON SPIGOT END.

The question of time in testing is an exceedingly interesting one. Perhaps I can illustrate it by speaking of the discussion which occurred in the American Society for Testing Materials as regards test-bars. The committee having that detail in charge brought the question before the Society, and one of the professors of a technical institution of Boston spoke on the question of the time of the test-bars in the test as influencing the ultimate breaking strength. Later he made some tests at our factory, and the result was that the element of time in testing test-bars was eliminated from the report. The time of the test has a certain influence, but not such a commanding influence as to make it a question to dwell on or an important point.

A pipe in a foundry is generally from one to two minutes in going through the press. As I have stood at the testing press where we test our 4- and 6-inch pipe, it is about a minute from the time it goes in to the time it comes out. The pressure has been on it even less than a whole minute, because part of the minute is taken up in the handling. In the case of larger pipe, of course the time has to be longer on account of the physical requirements in handling the machinery and the castings. We had one large contract for 60-inch pipe where the specification required that the test be kept on ten minutes, which, so far as I have learned from our foundry superintendents, developed nothing of value in the time of testing. Yet it is a question which I do not want to be settled offhand, and I should be glad to have you look into it, because anything which advances the manufacture is a thing to be adopted. I am only speaking of it as what we have learned from experience, that a long time in testing does not develop more strains than a short time in testing.

The allusion that has been made to the variation of angle of bends varying between 43, 44, and 45 degrees is one which I think was fairly explained; that is, the contraction of iron from a molten to a solid state is an uncertain question. The length of a straight pipe will vary from $\frac{1}{2}$ to $\frac{3}{4}$ inch simply from the contraction. That same thing happens in your curves, and on one side it will sometimes happen to be more than on the other. It is a thing which cannot well be avoided in manufacture. But unless the difference of curvature amounts to more than 4 or 5 degrees it becomes an insignificant quantity, because 4 or 5 degrees can be easily taken up in the adjustment of the spigots in the sockets.

The rings which Mr. Foss spoke about as being on the pipes after they are coated are something which is very annoying to the manufacturer. He doesn't like it, but what is he to do with a pipe after it comes out of the bath? He can't hold every pipe upon chains until it drains; he has got to lay them down. It would be unwise for buyers of pipe to ask for machinery to be made for suspending all pipe until cool, because it would add so much to the cost of the pipe that the game would not be worth the candle. Pipe has to be laid down and it has to be rolled to get it out of the way, and hence there will be rings.

I don't see how they can be avoided unless buyers of pipe wish to pay for placing the pipe on end, standing them around under cranes until they are cooled. Of course anything that the buyers of pipe want, the manufacturers will be ready to furnish and to accede to if it is understood in advance. The expense will be simply a question of so much per ton. But I really don't see any practical way of overcoming that matter of rings on the pipe. The pipe has to be laid down and rolled out of the way, unless there is some very elaborate arrangement for standing them on end.

The more important question, however, is the testing of specials. It is a very unsatisfactory thing on both sides. The question of testing pipe is a very simple thing, because after all a pipe is only a column, and to close one end you use a movable head and gasket which forces the pipe up against a stationary head with its gasket. The pipe is then subjected to a direct transmission of strains which cast-iron pipe is very well able to stand. Now when you undertake to test a cross or a tee you not only have to close the ends, but you have to close the arms. In closing those arms, especially in a large casting, sufficiently tightly to stand the pressure, you put new strains upon your castings, and strains which never occur in practice. So that, if castings are to be tested, it will involve a redesigning and using quite a quantity of extra metal. Now I am not giving this as an argument against testing specials, because, as I have said before, anything that the users of pipe want and will pay for they should have. But one of the things in connection with testing specials that must be borne in mind is that they will not only have to be tested for their work in the ground, but they will have to be designed to stand the unusual strain which the testing itself throws upon them.

I take it the reason that there has been no more trouble from the non-testing of specials than has been the case is because there is an extra amount of metal in the special, not for the sake of the foundryman getting an extra price, but because the cutting of a hole in the side of the pipe requires the replacement of an equal and more than equal amount of metal around the hole so that the casting will not break. To illustrate what I mean, we had a request at one time to test a lot of manhole branches. The long diameter of the manhole was parallel with the barrel of the pipe,

and we broke them right straight along. I suggested, Why not make the long diameter of manhole at right angles to the axis of the pipe? And instead of cutting a hole 18 inches in the side of the pipe, it was only 12 inches, and the casting stood. I only speak of that to show how you have got to replace the metal which you cut out of the side of the pipe for the opening, and more than replace it, because you don't put it where the strain really comes, but you put it at the side of the opening.

Now the question of testing, when it is practically and carefully worked out, comes down to the cost of testing and the cost of the additional metal which you put into the casting for safety. I should say it would be cheaper, speaking offhand, to furnish extra metal than to pay the expense of testing a special. If the buyers want them tested we will test them, but those two points had best be thought of, whether the cost of testing had not better be put into an extra weight of iron, and also the question of redesigning specials to stand the test strains.

Mr. Conard. Mr. President, in speaking of the pipe manufacturers having adopted a standard other than the New England specifications, I did not wish it to be inferred at all that I thought there was any antagonism on the part of the manufacturer as between what he thought should be the specifications and the specifications which had been adopted by the New England Water Works Association. I merely spoke of it to illustrate the fact, just as Mr. Wood said, that it was getting down to the basis of the best thing between theory and actual practice.

A little further on the question of the variation of the internal and external diameters: In making pipe designs you get a center for your core, and if the requirements as to variation of diameters between the largest and smallest diameter for a given nominal diameter are too great it will necessitate the making of a considerable quantity of additional fixtures, — socket irons, cups, centers, etc., and if the variation was very large possibly new core bars in order to take care of the amount of stock, as it is called in the foundry, which would work well. All of that would entail the making of a great many and various fixtures in order to make pipe of a given nominal diameter; and that is one of the reasons why, if the purchaser of pipe can reach the point where he feels

that he can possibly reduce the number of classes which he wishes to use, it will reduce the quantity of fixtures that would be necessary to get up for producing a given quantity of pipe, and that would tend to keep the cost of pipe within what the purchaser considers reasonable limits.

Mr. Foss. Mr. President, I should like to say a few words about curves being not as they are designed. That is a point I referred to, because the variation is always in one direction,— the deflection angle is always small. I measured fifteen or twenty 48-inch curves carefully after I had some trouble with them, and found the deflection angles were all smaller than specified. It becomes a matter of considerable importance on large pipe. On small pipe, 6, 8, 10, or 12 inches, it doesn't matter, but with a 48-inch or 60-inch pipe it does. The most you can deflect a 48-inch pipe by opening the joint is about one degree in good practice. If you have a corner where you want to use four $\frac{1}{16}$ curves to make a quarter turn, and each of them is out about 2 or $2\frac{1}{2}$ degrees, you need another special to make the turn, because you cannot do it by opening the joints. As the deflection angle is always too small, it seems to me some allowance might be made so that the curves will average about what they are designed for, if the error is due to shrinkage.

In regard to the bead on the pipe, I think there is a point in connection with the practical use of it which has been overlooked. I do not think it is of value so much for strength as for use in laying. It is a stop for the yarn, and is of use in raising the pipe when spacing it evenly in the socket. The method suggested of having a tapering socket to center the pipe in would not amount to very much in practice, because there is not one time in fifty that a pipe line is exactly straight. You are either laying it around a curve or over a hill, or something of that kind, so that you are deflecting from a straight line or grade all the time, and the spigots would not be centered in the sockets.

Mr. Wood. Mr. President, if it is a fact about the curve straightening itself out under contraction, — which I would be very glad to look into, because it is an interesting thing and something I never have had called to my attention, — it is a simple matter for the engineers to instruct their inspectors to have a

larger angle provided in the mold, so that the pipe will be eventually, when cooled, exactly the angle wanted. But in saying that I want to leave this thought, that the amount of contraction in cooling is a thing which I am afraid Nature takes care of very much more than mankind, and we will never be able to absolutely control it. We see that constantly in making flanged pipe, where we are expected to make them to an exact finished length and we never can do it without facing off the back of the flange and making the flange materially thicker in order to give metal to take the come and go of the contraction.

As to the matter of the bead, I think I made it clear that the conservatism in this country and in England will hardly permit its being taken off. As to its working in actual practice, there is no question whatsoever. It is discarded on so many thousand tons of pipe that its working in actual practice is a settled question, and it is settled to such an extent as this, if you will pardon me for a moment in explaining. We took quite a large contract for Java. The Dutch government felt uncertain as to the ability of Americans to make cast-iron pipe, and they sent their engineers over here to see whether it was possible for us to do it. I at once objected to their having no bead on their pipe. The engineers said they would put on their hats and go home, that they knew enough about the subject to know what they were talking about, and that this pipe was to have no bead or there was to be no contract. That is the way the people look at it who have worked it out in practice. You can make a good many objections to almost anything that is new, and yet in practice it has worked and does work satisfactorily.

PROCEEDINGS.

December Meeting.

Hotel Brunswick,
Boston, December 12, 1906.

William T. Sedgwick, President, in the chair.
The following members and guests were present:

Honorary Member.

Wm. T. Sedgwick. — 1.

Members.

C. H. Baldwin, L. M. Bancroft, F. A. Barbour, W. T. Barnes, J. W. Blackmer, George Bowers, G. A. P. Bucknam, F. H. Carter, J. C. Chase, J. W. Crawford, A. W. Cuddeback, A. W. Dean, H. P. Eddy, F. F. Forbes, W. E. Foss, F. L. Fuller, J. A. Gould, F. E. Hall, J. O. Hall, L. M. Hastings, T. G. Hazard, Jr., D. A. Heffernan, H. G. Holden, J. L. Howard, W. S. Johnson, E. W. Kent, Willard Kent, G. A. King, L. P. Kinnicutt, C. F. Knowlton, E. S. Larned, Thomas McKenzie, H. V. Macksey, N. A. McMillen, D. A. Makepeace, A. D. Marble, W. P. Mason, F. E. Merrill, Leonard Metcalf, F. L. Northrop, O. E. Parks, E. M. Peck, G. H. Palmer, E. B. Phelps, T. A. Peirce, Ransome Rowe, W. W. Robertson, H. W. Sanderson, E. M. Shedd, C. W. Sherman, G. H. Snell, W. F. Sullivan, R. J. Thomas, W. H. Thomas, L. D. Thorpe, D. N. Tower, W. H. Vaughn, F. B. Wilkins, G. E. Winslow. — 59.

Associates.

Builders Iron Foundry, by A. B. Coulters and F. N. Connet; Chapman Valve Manufacturing Company, by Edw. F. Hughes; Hersey Manufacturing Company, by Albert S. Glover, H. V. Macksey, and W. A. Hersey; International Steam Pump Company, by Samuel Harrison; Lead Lined Iron Pipe Company, by Thomas E. Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould; H. Mueller Manufacturing Company, by George A. Caldwell; National Meter Company, by C. H. Baldwin and J. G. Lufkin; Neptune Meter Company, by H. H. Kinsey; Rensselaer Manufacturing Company, by F. S. Bates and C. L. Brown; Thomson Meter Company, by E. M. Shedd; Union Water Meter Company, by F. L. Northrop and C. E. Merrill; R. D. Wood & Co., by W. F. Woodburn; Water Works Equipment Company, by W. H. Van Winkle. — 20.

GUESTS.

E. L. Field, chairman Water Board, Northfield, Vt.; J. H. Hill, commissioner, Lowell, Mass.; H. E. Cowan, I. N. Scribner, L. Vredenburgh, Boston, Mass.; A. E. Blackmer, superintendent Water Works, Plymouth, Mass.; C. W. Gilbert, Woburn, Mass.; C. H. Pierce, Springvale, Mass.; F. A. Collins, Philadelphia, Pa. — 9.

[Names counted twice. — 5.]

The Secretary read the following names of applicants for active membership, all of whom had been approved and recommended by the Executive Committee:

Non-Resident. — John Herbert McManus, West Hurley, N. Y., assistant engineer, Water Department, New York City; Perkins Boynton, Little Falls, N. J., bacteriologist and chemist, East Jersey Water Company, Little Falls, N. J.; Burton G. Philbrick, Brooklyn, N. Y., water sanitarian, Lederle Laboratories, New York; August E. Hansen, New York City, sanitary engineer with Williams, Proctor & Potts, New York City; Selskar M. Gunn, Iowa City, Iowa, assistant bacteriologist, State Board of Health, Iowa; Luther R. Sawin, Mt. Kisco, N. Y., chemist and bacteriologist, New York Water Department; Louis J. Richards, Elizabeth, N. J., health officer, Board of Health, Elizabeth, N. J.; W. F. Currier, Philadelphia, Pa., chemist and bacteriologist with Booth, Garrett & Blair, Philadelphia, Pa.; William J. Roberts, Pullman, Wash., professor of civil engineering, State Agricultural College, and consulting engineer, State Board of Health of Washington; Henry A. Pressey, Washington, D. C., designer and constructor of water works and sewerage systems; Arthur B. Cleaveland, Orman, S. D., United States Reclamation Service; E. F. Kitson, Norfolk, Va., supervising engineer for Southern Construction Company, etc.; John W. Maxcy, Houston, Tex., designer and constructor of water works and purification of public water supplies; Alex. J. Taylor, Wilmington, Del., engineer Sewer Department, Wilmington, Del.; L. R. Thurlow, health officer, Plainfield, N. J.; Charles F. Breitzke, White Plains, N. J., with John M. Farley, civil engineer, and in charge of construction of reservoir at Mt. Kisco, N. Y.; William H. Beers, Jr., chemist and bacteriologist, Water Department, Columbia, N. C.

Resident. — Nathaniel W. Hayden, Windsor, Conn., president and manager Windsor Water Company; Albert L. Sawyer, Haverhill, Mass., registrar Haverhill Water Works; Jas. A. Newlands, Middletown, Conn., assistant chemist and bacteriologist, Connecticut State Board of Health; William L. Butcher, Boston, Mass., assistant in office of chief engineer, Massachusetts State Board of Health; Herbert C. Emerson, M.D., director Emerson

Laboratory and member of Board of Health, Springfield, Mass.; Frederick W. Farrell, Springfield, Mass., chemist and bacteriologist, Emerson Laboratory, Springfield, Mass.

On motion of Mr. Fuller the Secretary was requested to cast one ballot in favor of the gentlemen whose names had been read, and he having done so they were declared duly elected members of the Association.

President Sedgwick. There is one matter which the Executive Committee has instructed me to bring before the meeting, and that is a vote of theirs, as follows:

" In view of the immense economic importance to the people of New England of the careful preservation of their forests, for the safeguarding of their water supplies and water powers, it is recommended that the following resolution be passed by the Association:

" That the President and Secretary be authorized and instructed to address an appeal on behalf of this Association to the members of the House of Representatives from New England urging each Representative to petition the Speaker without delay that the bill now pending, known as House Bill No. 13, which provides for the establishment of the Southern Appalachian and White Mountain forest reserves, be taken up for final action at an early day in the present session."

With reference to this action of your Executive Committee, I should like to say one word. The bill described here has been pending for some time in the National Congress. It has been passed by the Senate, it is strongly favored by the President, but we are told that it is being " held up " by the Speaker, who declines to allow it early consideration in the House. Those who are interested in this bill, and they are a very large number of the inhabitants of New England and of the eastern United States, — for this covers the Southern Appalachian as well as our own mountain region, — desire to get their members in Congress to bring it forward as quickly as possible. Moreover, while a resolution like this passed by the Association to-day will be of value, the most valuable thing which can be done, and the most helpful, will be for every one of us to write a letter to his Representative — not to his Senators, but to his Representative in

Congress — or to see him, personally, and urge him to advance so far as he can the interests of this bill.

This Association does not go into politics, but your Executive Committee does not think that this is politics. This is literally self-preservation. If the White Mountain region is to be denuded the damage to our New England water powers will be very great. Here is a bill, the passage of which is desired by a very large proportion of our people, and which we, as an association of water works men, feel deeply interested in. I would, therefore, respectfully urge you to get into touch, if you can, with your own Representatives from Massachusetts, Connecticut, Rhode Island, New Hampshire, Vermont, and Maine, and ask them to push this thing forward as fast as they can. The resolution is a formal one, and you can quote it to your Representative if you like. It comes before you with the recommendation of your Executive Committee that it be passed. What is your pleasure with regard to it?

On motion of John O. Hall it was unanimously voted that the resolution be accepted and adopted.

The first paper of the afternoon was by Mr. E. S. Larned, of Boston, Mass., and was entitled "Use and Tests of Cement and Concrete." Mr. Frank L. Fuller and Prof. William P. Mason took part in the discussion. The second paper was on "The Explosion of the Saratoga Septic Tank," by Dr. William P. Mason, professor of chemistry Rensselaer Polytechnic Institute, Troy, N. Y. This paper was discussed by Prof. L. P. Kinnicutt, Mr. Harrison P. Eddy, Mr. John A. Gould, Mr. Frank A. Barbour, Mr. Earle B. Phelps, and the President.

Adjourned.

Annual Meeting.

Hotel Brunswick,
Boston, January 9, 1907.

The President, Prof. William T. Sedgwick, in the chair.

The following members and guests were present:

Honorary Member.

Wm. T. Sedgwick. — 1.

Members.

S. A. Agnew, M. N. Baker, C. H. Baldwin, L. M. Bancroft, G. W. Batchelder, C. A. Bogardus, J. W. Blackmer, George Bowers, E. C. Brooks, G. A. P. Bucknam, James Burnie, C. E. Childs, J. C. Chase, R. C. P. Coggeshall, M. F. Collins, W. R. Conard, A. O. Doane, J. N. Ferguson, A. D. Flinn, J. H. Flynn, G. H. Finneran, F. F. Forbes, W. E. Foss, A. D. Fuller, F. L. Fuller, W. B. Fuller, J. C. Gilbert, D. H. Gilderson, A. N. French, A. S. Glover, J. O. Hall, J. C. Hammond, Jr., V. C. Hastings, D. A. Heffernan, H. G. Holden, W. S. Johnson, E. W. Kent, Willard Kent, Patrick Kieran, G. A. King, C. F. Knowlton, S. H. McKenzie, Hugh McLean, N. A. McMillen, A. E. Martin, W. E. Maybury, John Mayo, F. E. Merrill, Leonard Metcalf, H. A. Miller, F. L. Northrop, E. M. Peck, Wm. Naylor, J. H. Perkins, E. M. Shedd, C. W. Sherman, Sidney Smith, G. H. Snell, G. A. Stacy, W. F. Sullivan, H. A. Symonds, J. A. Tilden, R. J. Thomas, W. H. Thomas, J. L. Tighe, D. N. Tower, G. W. Travis, W. H. Vaughn, C. A. Townsend, C. K. Walker, J. C. Whitney, G. E. Wilde, F. B. Wilkins, G. E. Winslow. — 74.

Associates.

Harold L. Bond & Co., by Harold L. Bond; Chapman Valve Manufacturing Company, by Edw. F. Hughes; Coffin Valve Company, by F. E. Adams; William H. Gallison Company, by H. E. Stilphen; Hersey Manufacturing Company, by Albert S. Glover, J. A. Tilden, W. A. Hersey, A. H. McAlpine; International Steam Pump Company, by Sam'l Harrison; Jenkins Bros., by J. D. Stiles; The Fairbanks Company, by F. A. Leavitt; Lead Lined Iron Pipe Company, by T. E. Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould; National Meter Company, by C. H. Baldwin, J. G. Lufkin; Neptune Meter Company, by H. H. Kinsey; Rensselaer Manufacturing Company, by C. L. Brown; Platt Iron Works Company, by F. H. Hayes; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by E. M. Shedd; Union Water Meter Company, by F. L. Northrop; United States Cast Iron Pipe & Foundry Company, by F. W. Nevins; R. D. Wood & Co., by W. F. Woodburn; Water Works Equipment Company, by W. H. Van Winkle. — 24.

Guests.

F. L. Weaver, A. Weaver, E. B. Carney, C. A. Nelson, Lowell, Mass.; E. T. Harvell, Rockland, Mass.; F. L. Clapp, superintendent Water Works, Stoughton, Mass.; Clifford Baylies, water registrar, New Bedford, Mass.; Edwin Leavitt, Somerville, Mass.; N. P. Potter, Braintree, Mass.; Samuel W. Hoyt, Jr., South Norwalk, Conn.; A. E. Blackmer, Plymouth, Mass.; George F. Whitney, Natick, Mass.; John J. Nugent, water commissioner, and Frank Woodbury, 2d, chairman Water Board, Beverly, Mass.; Frank Smith, Kineo, Me.; Charles H. Rollins, commissioner, Watertown, Mass.; H. E. Cowan, Boston, Mass. — 17.

[Names counted twice. — 5.]

After dinner had been served President Sedgwick called the meeting to order and spoke as follows:

President's Address.

Gentlemen of the Association, — A wise custom makes it incumbent upon the retiring officers of your Association to give at the annual meeting some account of their stewardship. In conformity with this custom I propose in a few words to call your attention to the principal events of the year that has gone, to touch upon the present and prospective condition of the Association, and then to make way for those who are nearer the field of action — the Secretary, the Editor, the Treasurer — than is your President.

Associations like ours date back, as you may be interested to know, for about three hundred years. Almost exactly three hundred years ago a little band of scientific students — we can hardly call them scientific men — in Rome, got together, in the absence of any prevailing popular scientific enthusiasm, in the absence of events of stirring scientific interest, such as surround us to-day, but yet filled with the love of knowledge, and with an enthusiasm for Nature and for the study of Nature, and formed a body which they called the Society of the Lynx, that is to say, of the keen-eyed. That society, which is known as the *Accademia dei Lincei,* was the first in a long series of scientific societies and technical organizations like our own from that day to this. It still exists in Italy and is the leading scientific organization of that now strong, active, and enterprising country. It was followed by the organization of the Royal Society of London, that by the French Academy of Paris, and that by a similar society in Germany; and from that day to this earnest and thoughtful and enthusiastic students of Nature and the Arts have gathered themselves together, as we have done in this Association, for mutual benefit and for the study of the things that interest us in this world.

The year that is gone has shown no great change in the characteristics of our Association. It still remains an organization for mutual benefit, and it still has the same objects in view which it has had from the beginning. Some of those I may touch upon in a moment. But first let me say that we are rapidly becoming

a body of more than local importance. Our numbers are drawing near the 700 line. They have increased this year from 645 in all to 684 in all. Our Associates have fallen in number from 53 to 51; our Honorary Members have increased from 8 to 15, and one of our Honorary Members, Mr. Croes, a justly famous engineer, has died. The decrease in our Associate membership is, doubtless, due in large measure to the tendency of the times to combine, and thus diminish the number of industrial and similar organizations. The growth in our active resident and non-resident membership seems to me strong testi mony to the usefulness of the Association for never before has there been a time when men have been invited to join so many organizations or pay so many fees as to-day. When, therefore, we find 600 men and more continuously connected with the New England Water Works Association and paying their fees with regularity and promptness we cannot help but feel that they get something out of the Association; in other words, that they find it useful.

Before leaving the subject of membership, upon which I do not care greatly to dwell, I do wish to say one word about our Honorary Members. It has seemed to me for some time, in fact ever since I was myself elected an Honorary Member, — thanks to your courtesy and consideration, — that our list of Honorary Members was not yet such as was worthy of the Association; I mean that it did not contain many of those distinguished names which might well be upon our rolls with honor to the Association and with honor to themselves. I was, therefore, very glad when the Executive Committee at the Annual Convention proposed, and when the Association elected, a number of the most distinguished men in the United States more or less closely connected with water works, to honorary membership in this Association. It became my pleasant duty to notify these gentlemen of their election, and I have here the letters which they wrote, accepting — as they all did — honorary membership in the Association and the honor and distinction conferred upon them by you.

I propose now, at the risk of taking a little time, to read extracts from these letters, because I take it to be a matter of marked and permanent interest to a body like this, when men of distinction, such as these whom we have elected and who have accepted

honorary membership, say some of the things which they have said in their letters.

I will read first the letter of acceptance from the eminent engineer, Mr. Joseph P. Davis. I will omit, as a rule, personal references and the address and signature:

"Your favor of the 6th inst., notifying me that I have been elected an Honorary Member by the New England Water Works Association, is at hand. I accept the election with great pleasure. Please give my sincere thanks to the Association for the honor conferred, an honor which I appreciate highly. Also please accept my thanks for the very kind terms in which you notify me of the election."

I may say that substantially the same letter was sent to all, to the effect that the Association had pleasure in conferring honorary membership upon the person addressed, in view of his distinguished services to water works science.

The next letter is from Mr. Edwin Reynolds, of Milwaukee, or rather from Mrs. Reynolds, because, I regret to say, of the illness of Mr. Reynolds. She says:

"Mr. Reynolds has been confined to his bed most of the time for the last nine months. He wishes me to say, in answer to your communication, that he highly appreciates the distinction of being an Honorary Member of your society and accepts the election with pleasure."

The next is from Mr. John T. Fanning, of Minneapolis, who says:

"I have received your letter announcing the honor conferred by the New England Water Works Association at its recent meeting in the White Mountains. I appreciate the kind words with which you have accompanied the announcement, and assure you that I appreciate such honoring remembrance of an absent member by the Association. I shall be pleased to accept the honorary membership which the Association courteously voted. I had hoped to be present at the September meeting, but was unfortunately called to an engagement in Canada just at that time."

The next is from Mr. E. D. Leavitt, of Cambridge:

"I accept with pleasure the election as an Honorary Member of the New England Water Works Association, a society whose

good work makes it *a public benefactor.* With thanks for the honor conferred, I remain,

"Sincerely yours."

The next comes from Mr. Rudolph Hering:

"I wish to convey to you my high appreciation of the honor which the Association has kindly conferred upon me, and to thank you for your kind expressions. Of course I could not do otherwise than accept the election, which brings so much honor with it, and I do so with the feeling that, while I hardly deserve what you say, my life may yet be useful in advancing the science of engineering in theory and practice, as it has always been my effort in a small way to do."

The next is from Dr. Henry P. Walcott, the distinguished chairman of the State Board of Health of Massachusetts, and a member of the Metropolitan Water and Sewerage Board of the same state:

"I have your kind note informing me of the action of the New England Water Works Association in electing me to an honorary membership in the Association. I accept the honor with great pleasure, for I have a high regard for the important work of the Association, and as a member of the State Board of Health have more than once been greatly indebted to it for advice and assistance."

From Mr. F. P. Stearns, formerly chief engineer of the State Board of Health of Massachusetts and later of the Metropolitan Water and Sewerage Board of Massachusetts:

"Your letter containing the information of my election as an Honorary Member of the New England Water Works Association was handed to me yesterday on the train as I was leaving Boston. Although I have not been able to attend many meetings of the Association in recent years, I have always highly appreciated the very good work which it has done, this result being due to the many able men enrolled in its membership and to their willingness to work and to contribute freely to the general fund of information on water works management and construction. Having such an opinion of the Association, I can and do appreciate most highly the honor conferred upon me by this election. Permit me in accepting membership in the Association to thank you, and through you the Association, for its action."

And finally from Mr. Hiram F. Mills, the eminent hydraulic engineer, who has been for so many years the devoted and self-sacrificing engineer-member of the State Board of Health of Massachusetts:

"Your very kind letter informing me of my election as an Honorary Member of the New England Water Works Association is received. It is about twenty years since at a meeting in Boston I told the members of the Association what the State Board of Health of Massachusetts proposed to do in order to improve the quality of water used in public water supplies, and asked their coöperation. In the meantime, the members within the state, almost to a man, have intelligently and cordially cooperated with the board in its efforts to render the water supplies more helpful, for which the board and their own communities have reason to thank them. The effort to improve, and the questions which the members of the Association have found it profitable to consider, have raised the standard of the men having charge of such work throughout the bounds of the Association, and I am happy to receive from such a body of men the expression of this honor."

Now, gentlemen, these well known and distinguished names stand to-day upon our roll as Honorary Members of this Association, and it seems to me they confer dignity upon and add luster to it. Let us be careful that as we go on in the future we add to our honorary membership only men of similar rank; and in adding to our active resident and non-resident and to our associate membership, let us also watch carefully over the quality and character of the men whom we invite to become members. At the same time let us not be exclusive. There are in particular a great many *young* men who ought to belong to this Association, so that they may get the benefit of contact with older men and of the papers which are read here, — the social side and the intellectual side. I think we have all been a little negligent in not bringing in more of the young men. Let us see if in the future we cannot add more of them to our active membership.

The object of this Association is, first and foremost, social intercourse. By that I mean the friction of mind on mind, the exchange of ideas, and especially of technical and professional

ideas, discovering whether we are up to date or behind the times by contact with our neighbors who may be more alert than we are in particular directions. We ought never to allow at our meetings and luncheons the formal papers to crowd out that part of our work. We ought, therefore, always to have the hour of meeting such that there shall be opportunities for social conference before or after our meetings, and generally, of course, before.

Most of us come here to get information, but we should remember that we ought to give information too. I have repeatedly urged upon the members the necessity of bringing here the results of the practical experience of every-day life, of work in the field, by noticing things that are interesting or suggestive and bringing them here and talking about them. If this Association degenerates so that our meetings become merely a place for the giving of lectures or for the reading of long disquisitions, it will never fulfill its principal function. *Discussion* is, and always will be, the essence of the successfulness of any such association as this, — the give and take, the quick answer which comes to the new idea thrown out by some one, — resisted, or accepted, or illustrated or improved upon. We need, therefore, to be careful, especially you gentlemen who are superintendents in actual service and familiar with practical details, to look out for the glib talkers — the professors and similar people — who can, perhaps, lecture to you by the hour but who, perhaps, after all, cannot help you half so much as your neighbor who may be far less fluent but far more expert in actual water works warfare. We need, therefore, to give careful attention to our *programs*. And we are not alone in this matter, for it is felt by many a society to-day that there is danger of being swamped by long papers which allow little or no time for discussion. We must have the vital discussion if we would remain successful.

In this connection a suggestion has been made by Mr. Baker that it is a pity that many of our papers are not submitted in print so that written discussions can be sent in. That is done, as you know, in many associations and societies, and it is well worth thinking of for ours. If we are becoming, almost in spite of ourselves, a body of national importance, if we have now nearly

700 members, it certainly becomes a question whether we ought not to adopt some such plan, so that the wider circle of those members who cannot come to our regular meetings may take part in our discussions. In that way it is believed that we might also get from them much that would be valuable for ourselves.

It has seemed to me, watching things as your executive officer for the last year, that on the whole the arrangements for our meetings are fairly good. If we come in punctually at one o'clock, and if our luncheon is served as rapidly as it should be, we still have time enough left for other things before the afternoon has gone and members must take trains for suburban cities or towns. But it is important that we shall be able to begin *punctually* at one, and also, of course, that the luncheon shall be quickly served.

Although often dealing with sanitary matters, we have not infrequently met under most unsanitary conditions, in rooms overheated as they used to be at Young's Hotel, and ill ventilated as has often been the case here. This matter requires very careful attention, for if one is to go home from a meeting refreshed and not tired out so that he isn't good for much the next day, it is highly important that he should have fresh air and not be overheated during the afternoon. And this raises a question which you must often have thought of, and which I have often thought of, viz., whether in this metropolis of New England we haven't now reached the time when all our engineering and scientific societies and perhaps some others, should get together and have a building of their own, a club house, if you like, with rooms for dining and with rooms for resting and sitting about and smoking and talking, — for the social side of our work, which is quite as important as the reading of papers.

I know that this question has been discussed in the past and dismissed as impracticable, but New England is getting larger all the time, associations are multiplying, wealth is increasing, and it does seem to me that the time ought to be very near, if it has not now arrived, when we should have in Boston, as they have in New York, a building adapted for work of our kind. We shall need such a building more in the future than we do to-day. While our hotels are good to us and do the best they can under

the circumstances, we ought to have rooms ventilated with the latest appliances, so that when smoke forms here it shall be carried away, as it is, for example, in the Hotel St. Regis, in New York. If you have ever dined there and seen people smoking in the dining room with ladies, — smoking anywhere, without any odor of smoke remaining in the room, — you know what good ventilation to-day is. But most people do not know, and many who do know do not seem to care. We ought to have a building used by all the scientific societies, ventilated in the latest and best way, in charge of a janitor who should be well paid and who wouldn't overheat it, but would manage things as any scientific expert who has studied the subject could tell him how to manage them. Then we could sit through one of our meetings and go out, not with a full head — yes, I hope with a full head, but not with a headache — and refreshed by good ventilation, rather than wearied by overheating and poor ventilation.

Our year has certainly been a successful one, and the editor will tell you about the JOURNAL. It seems to me that the JOURNAL is something which we want to foster with the greatest care. It is from this that our absent members get their money's worth. They get the JOURNAL, they know what has been going on, and they get the benefit of all the papers presented. The question is whether we ought not to extend the scope of the JOURNAL somewhat, whether we ought not to seek to publish still more papers of general interest relating to water and water supplies; and it seems to me that as long as we have editors such as we have thus far always had, careful and patient workers, we might afford, perhaps, to put more money into the JOURNAL, — which means into the salary of the editor and into the printing, — and extend our work somewhat in that direction, gradually perhaps, at first, but considerably later.

You remember that the American Water Works Association met here during the summer, and that our relations with the officers and members were of the most agreeable character. Your President spoke for our Association at the opening meeting in Huntington Hall, and the meeting of that Association in what we may consider our own territory was most welcome to us, and I believe most agreeable to the members of that organization. It

was at the same time very successful. There need be and should be no conflict whatever between these two bodies, — the larger national association covering the whole of these United States from the Atlantic to the Pacific and from Canada to Mexico, and the New England Association having a strong local basis here in New England but reaching out as far as experience and the demand show it wise to reach.

Two or three legislative matters of interest have come up during the year, one of them being the matter of boating on Great Ponds, in which our Association threw its influence in favor of the protection of the water supplies of the state, as I hope it may always continue to do. Another was a resolution and an effort in support of the hydrographic work of the United States Geological Survey; and the third an attempt to aid those who are seeking to provide a forest reservation in the White Mountains — something which means so much to us in connection not only with water supply but also with water power.

And that leads me to say, gentlemen, that our Association, it seems to me, runs a little too much to water supplies, municipal water supplies, and not quite enough to other aspects of water works, — to water for fire protection and especially to water powers. New England is full of water powers and there are many interesting questions coming up which we ought to hear more about from time to time than we have thus far heard at our meetings.

It would be easy for me to take up all the afternoon in talking about the past and the future of the Association, but I will spare you, simply remarking that never was there a time, perhaps — I think I may even omit the "perhaps" — never was there a time when questions of water supply and water power were more important than they are to-day, — of water supply because of the growth of city populations. The terrible epidemics of typhoid fever to-day in Scranton and in Pittsburg, Pa., lend point to my statement in that direction. The value of power in every direction to-day, the demand for power, the possibilities of profit in power, likewise make the subject of water power more important than ever before.

There is, then, ample room for our Association, ample room

for its further growth and extension, and if we all keep up our loyalty to it, if we all strive to work for it as we ought to do, there is no reason why its membership and influence should not continue to increase. I think, however, we want to beware of one thing. All of us are who busy, — and who of us is not? — naturally wish and expect the officers of the Association to take all the trouble, to run it, and to look out for its interests. That is a comprehensible point of view with any one who is busy. But the Association will never reach its highest usefulness until every member of it feels his individual duty toward it, particularly with respect to helping out as to its work and as to its programs. It is conceivable that we might have a large program-committee which should be a kind of drag-net especially devised for getting those practical experience papers upon which I have harped so long and so often, and which do not seem to be readily forthcoming. If every one of us does his duty by the Association he will get out of it even more than he puts into it, for after all that is about what we do in this world: we get out of things very much what we put into them, and if a man will put work into the Association and devotion and affection, he will be likely to reap a rich reward from it.

There came in during the year one letter which I should have read at an earlier meeting, but which now I am rather glad I did not read before. It seems we have a member in Plymouth, Mass., eighty-five years old, who has a real and abiding regard for this Association. I haven't the pleasure of his acquaintance myself, but his name is Bagnell. He writes to the Secretary in a very good hand as follows, — and if all of us at the age of eighty-five are able to write letters in his spirit we shall be testifying, as this writer does, to a deep regard for the Association:

"Willard Kent:

"*Dear Sir,* — I suppose my membership in the Association is closed. It is just as well. I am getting along in years. I was born in the year 1822. I am in the doctor's hands and have been for the last four months. I shall never go out of Plymouth again until I go across the silent river. I send my last year's dues so I can be square with the world, and so I can die happy.

God bless the New England Water Works Association. Yours until death, R. W. BAGNELL, Plymouth."

[Applause.]

In this touching and affectionate testimony from an old member it seems to me we see an example of what we may all strive ourselves to give, and an attitude which we may all strive ourselves to imitate. [Applause.]

PROFESSOR KINNICUTT. Mr. President, I think we have all listened with a great deal of pleasure to this letter from Mr. Bagnell, and I move that the Secretary be directed to transmit to him the cordial greeting of the Association, and the request that he remain a life member, all future dues being remitted. [Applause.]

THE PRESIDENT. The motion is made and seconded, and I am sure that every man of us will be glad to vote for it. I do not need to ask for any remarks, but will simply put the motion. [Adopted unanimously.]

MR. COGGESHALL. It may be proper for me to state that Mr. Bagnell was one of the 18 who organized this Association in Young's Hotel, in June, 1882.

REPORT OF SECRETARY.

The Secretary submitted the following report:

Mr. President and Gentlemen of the New England Water Works Association, — I have the honor to submit the following report of membership, receipts, and disbursements of the New England Water Works Association for the year ending December 31, 1906.

MEMBERSHIP.

The total membership of the Association, January 1, 1906, was	645
The present membership is	684
A net increase during the year of	39

MEMBERS.

January 1, 1906.	Total members		584
	Withdrawals:		
	Resigned	8	
	Died	4	
	Transferred to Honorary Membership	3	
	Dropped	38	53
	Carried forward		531

	Brought forward			531	
	Initiations:				
	January	3			
	February	12			
	March	6			
	June	8			
	September	11			
	November	7			
	December	17	64		
	Two members elected in 1905, but qualified in 1906		2	66	
	Reinstated:				
	Members dropped in 1905		9		
	Members dropped in 1906		12	21	618

HONORARY MEMBERS.

January 1, 1906.	Honorary members	8		
	Died	1	7	
	Transferred from membership	—	3	
	Elected		5	15

ASSOCIATES.

January 1, 1906.	Total associates		53	
	Withdrawals:			
	Resigned	4		
	Dropped	4	8	
			45	
	Initiations:			
	January	1		
	September	2	3	
	Reinstated:			
	Associates dropped in 1906		3	51
January 1, 1907.	Total membership			684

SUMMARY OF RECEIPTS AND DISBURSEMENTS OF THE NEW ENGLAND WATER WORKS ASSOCIATION FOR THE YEAR 1906.

RECEIPTS.

Initiations		$283.00
Annual dues:		
Members	$1 746.00	
Associates	765.00	
Fractional Dues:		
Members	49.00	
Associates	10.00	
Past Dues	68.20	
Total dues		2 638.20
Carried forward		$2 921.20

Brought forward,	$2 921.20
Advertisements	1 756.25
Subscriptions	184.00
Journals sold	164.85
Sundries	247.88
	$5 274.18

DISBURSEMENTS.

Journal	$1 514.37
Stationery	556.57
Assistant Secretary	540.00
Rent	400.00
Editor	300.00
Advertising Agent	255.00
Incidental expenses	222.20
Secretary	200.00
Reprints	166.30
Ladies' Complimentary lunch	147.50
Stenographer	126.50
Membership list	116.00
Stereopticon	93.20
Music	80.00
Printing pipe specifications	79.75
Badges	30.00
Insurance	15.00
Library	2.75
Total	$4 845.14
Receipts in excess of expenditures	$429.04

At the present time there is due the Association:

For advertisements	$81.25
For initiations and dues	34.00
For Journals	11.00
For specifications	1.40
	$127.65

I know of no outstanding bills against the Association.

Respectfully submitted,

WILLARD KENT, *Secretary.*

On motion of Mr. M. F. Collins, the report of the Secretary was accepted and ordered to be printed and placed on file.

Report of Treasurer.

The Treasurer submitted the following annual report:

LEWIS M. BANCROFT, TREASURER,
In account with the New England Water Works Association.

RECEIPTS.

1906				
Jan. 5	Balance on hand		$2 888.73	
Aug. 1	Dividend, Peoples Savings Bank		53.16	
Dec. 1	Dividend, Mechanics Savings Bank		39.60	
Feb. 12	Rec'd of Willard Kent, Sec'y,	$959.60		
April 6	" " " "	1 544.46		
June 6	" " " "	402.30		
July 30	" " " "	495.77		
Sept. 20	" " " "	225.87		
Oct. 6	" " " "	201.00		
Dec. 13	" " " "	913.65		
1907				
Jan. 5	" " " "	531.53	5 274.18	
			$8 255.67	

EXPENDITURES.

Paid bills, as per itemized statement		$4 845.14
BALANCE ON HAND.		
Deposit Peoples Saving Bank, Worcester	$1 559.21	
Deposit Mechanics Savings Bank, Reading	1 161.95	
Deposit First National Bank, Reading	157.84	
Cash on hand	531.53	
		3 410.53
		$8 255.67

READING, MASS., January 5, 1907.

LEWIS M. BANCROFT, *Treasurer.*

DETAILED STATEMENT OF BILLS PAID.

1906.		
January 27	W. N. Hughes, envelopes and printing	$89.25
	D. Gillies' Sons, printing	4.75
	Harry L. Thomas, expenses auditing accounts	2.70
	R. C. P. Coggeshall, expense auditing accounts	4.40
	W. W. Robertson, expense auditing accounts	4.56
	Thomas P. Taylor, stereopticon	10.00
February 13	Miss J. M. Ham, assistant secretary, salary, January, 1906	45.00
March 5	Hub Engraving Company, plates	21.12
	L. M. Bancroft & Son, treasurer's bond	15.00
	William E. Whittaker, tracings	3.50
	Samuel Usher, standard specifications	32.50
	Miss Rosetta Key, singing, February 14	25.00
	W. N. Hughes, postal cards and printing	8.25
	Miss J. M. Ham, salary for February	45.00
	Helen S. Patterson, cards	36.00
16	Hub Engraving Company, plate	3.60
	D. Gillies' Sons, letter heads and envelopes	81.34
	Boston Society of Civil Engineers, rent to February 28	100.00
	Charles W. Sherman, salary to April 1	75.00
	Charles W. Sherman, postage, etc.	4.94
April 6	Robert J. Thomas, services, advertising agent, to April 1	73.75
	Samuel Usher, March JOURNAL	351.05
	Willard Kent, salary to April 1, 1906	50.00
	Willard Kent, music, guest tickets, etc.	100.50
	B. D. B. Bourne, stereopticon	10.00
	Miss J. M. Ham, salary for March	45.00
26	Samuel Usher, reprints	38.00
	Bacon & Burpee, reports of January and March meetings	26.50
	W. N. Hughes, printing circulars	2.75
	William E. Whittaker, tracings	3.50
	Miss J. M. Ham, salary for April	45.00
May 5	Samuel Usher, list of members	116.00
	Hub Engraving Company, plates	28.52
19	D. Gillies' Sons, printing	4.00
	W. N. Hughes, printing and binding	49.55
June 7	Miss J. M. Ham, salary for May	45.00
	Miss J. M. Ham, postage, telephone, express	45.15
	Amount carried forward	$1 646.18

	Amount brought forward	$1 646.18
June 7	Miss J. M. Ham, copying for Meter Rates Committee	1.75
	Samuel Usher, standard specifications	47.25
8	The Brunswick	3.00
25	W. N. Hughes, printing tickets	2.25
	Chas. W. Sherman, salary three months to July 1	75.00
	Chas. W. Sherman, postage and express	6.50
	Miss J. M. Ham, salary for June	45.00
	R. J. Thomas, services advertising agent to July 1,	62.25
	Willard Kent, salary to July 1, 1906	50.00
	Willard Kent, guest tickets, postage and express	17.50
July 23	Samuel Usher, June Journal	312.80
	W. N. Hughes, cash book	12.00
	J. M. Ham, salary for July (part)	35.00
September 7	Samual Usher, reprints	50.05
	W. N. Hughes, envelopes and printing	38.00
	Boston Society of Civil Engineers, rent to May 31,	100.00
	D. Gillies' Sons, printing	14.60
	J. M. Ham, bal. July and August, salary	55.00
24	O. G. Barron, postals	7.00
	The Somerville Journal Company, printing	1.50
	Charles W. Sherman, salary to October 1	75.00
	Charles W. Sherman, postage on Journal	5.00
	Samuel Usher, reprints	1.50
	Willard Kent, salary to October 1, 1906	50.00
	Willard Kent, cash paid account of Annual Convention	184.00
	Frank E. Merrill, expense paid acc't T. P. Taylor	18.00
October 8	W. N. Hughes, letter heads	5.00
	Boston Regalia Company, badges	30.00
	Thomas P. Taylor, stereopticon	35.20
	J. M. Ham, salary for September	45.00
	D. Gillies' Sons, programs	13.50
24	Miss A. N. Hill, typewriting for Committee on Uniformity of Hydrants and Valves	4.85
	Hub Engraving Company, plates	50.68
	Wm. E. Whittaker, tracings	8.50
	Bacon & Burpee, report of September meeting	76.25
November 3	Boston Society of Civil Engineers, rent to August 31,	100.00
	Miss J. M. Ham, salary for October	45.00
	Miss J. M. Ham, sundry expenses	82.20
22	Hub Engraving Company, plate	1.18
	Samuel Usher, September Journal	389.15
	Amount carried forward	$3 802.64

	Amount brought forward	$3 802.64
November 22	R. J. Thomas, services, advertising agent to November 1	61.75
	J. B. Fillebrown, music, November meeting	10.00
	Thomas P. Taylor, stereopticon, November 14	10.00
	Miss J. M. Ham, salary for November	45.00
December 12	Samuel Usher, reprints	43.00
	Hub Engraving Company, plates	17.20
	Wm. E. Whittaker, tracings	3.50
	D. Gillies' Sons, circulars	12.50
29	Hub Engraving Company, Plates	13.91
	Boston Society of Civil Engineers, rent to December 1, 1906	100.00
	W. N. Hughes, printing	11.00
	Charles W. Sherman, coypright and postage	2.00
	Chas. W. Sherman, salary to December 31, 1906	75.00
	Thomas P. Taylor, stereopticon	10.00
	Miss J. M. Ham, salary to December 31, 1906	45.00
	Miss J. M. Ham, express, telephone, etc.	32.48
	Bacon & Burpee, reporting November and December meetings	23.75
	Willard Kent, salary to December 31, 1906	50.00
	Willard Kent, sundry expenses	34.00
1907.	Samuel Usher, printing December JOURNAL and reprints	344.66
January 5	D. Gillies' Sons, circulars	14.50
	R. J. Thomas, services advertising agent to January 1, 1907	57.25
	La Rue Viedenburg, services	10.00
	Prof. Geo. N. Cross, lecture on White Hills	16.00
		$4 845.14

On motion of Mr. Frank L. Fuller, the report of the Treasurer was accepted and ordered to be placed on file.

REPORT OF EDITOR.

The Editor submitted the following as his annual report:

BOSTON, January 9, 1907.

To the New England Water Works Association, — The following is my report for the year 1906, as editor of the JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

The accompanying tabular statements show in detail the amount of material in the JOURNAL; of receipts and expenditures on account of the JOURNAL

for the past year; and a comparison with the conditions of the six preceding years.

Size of Volume. — The volume is considerably smaller than that of the preceding year, as the latter had an unusual amount of material presented at the New York Convention. It is, however, larger than any other preceding volume of the JOURNAL. In comparison with this statement, it is gratifying to note that the gross cost is less than that for the three preceding years, and that the net cost, considering the size of the Association and number of pages, less than ever before since these reports have been made.

Illustrations. — The total cost of illustrations in the JOURNAL for the year has been $271.71, or 10.6 per cent. of the gross cost of the volume.

Reprints. — The usual fifty reprints of papers have been furnished to authors without charge. Some free reprints have also been furnished to members who have contributed important discussions which practically amounted to papers in themselves. The net cost to the Association of the reprints has been $91.55, or $3.98 for each of the 23 papers published during the year.

Circulation. — The present circulation of the JOURNAL is:

Members (all grades)	684
Subscribers	60
Exchanges	23
Total	767

an increase of 62 over the preceding year.

Advertising. — The December issue contained 26.08 pages of paid advertising, which if maintained throughout a year would mean an annual income from this source of $1 740. A year ago the figures were 28.08 and $1 985, showing a considerable decrease during the year.

Pipe Specifications. — During the year pipe specifications have been sold to the amount of $132.10; the expense for reprinting specifications during the year has been $79.75, leaving a net gain of $52.35 for the year. Our net income from this source a year ago was $56.70, so that the total net income at the end of 1906 has been $109.05. Of course the original cost of typesetting and illustrating these specifications was charged to the JOURNAL in which the specifications were first published, but the net receipts have now been sufficient to practically repay this expense. We still have on hand a fair supply of the specifications, enough, if sold at retail, to bring in some $40, more or less.

I know of no outstanding bills against the Association on account of the JOURNAL.

Respectfully submitted,

CHARLES W. SHERMAN, *Editor.*

TABLE No. 1.

STATEMENT OF MATERIAL IN VOLUME XX, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1906.

Number.	Date.	Pages of Papers.	Proceedings.	Total Text.	Index.	Advts.	Cover and Contents.	Inset Plates.	Total.	Cuts.
1	March	97	29	126	–	31	4	8	169	9
2	June	98	12	110	–	28	4	6	148	10
3	September	125	17	142	–	28	4	12	186	6
4	December	108	9	117	7	28	4	3	159	16
	Total	428	67	495	7	115	16	29	662	41

TABLE No. 2.

RECEIPTS AND EXPENDITURES ON ACCOUNT OF VOLUME XX, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1906.

RECEIPTS.		EXPENDITURES.	
From advertisements . . .	$1 756.25	For printing JOURNAL .	$1 539.16
From sale of JOURNALS . .	164.85	For preparing illustrations	155.21
From sale of reprints . . .	74.75	For editor's salary . . .	300.00
From sale of cuts	5.80	For editor's incidentals .	31.44
From subscriptions	184.00	For advertising agent's commissions	255.00
	$2 185.65	For reporting	126.50
Net cost of JOURNAL . . .	$387.96	For reprints and advance copies	166.30
	$2 573.61	Gross cost of JOURNAL . .	$2 573.61

TABLE No. 3.

COMPARISON BETWEEN VOLUMES XIV, XV, XVI, XVII, XVIII, XIX AND XX, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

	VOL. XIV. 1899–1900.	4 NUMBERS OF VOL. XV. 1900–1901.	VOL. XVI. 1902.	VOL. XVII. 1903.	VOL. XVIII. 1904.	VOL. XIX. 1905.	VOL. XX. 1906.
Edition (copies)	1 100	1 200	1 200	1 200	900	900	900
Average membership	583	586	571	587	596	625	665
Pages of text	345	363	403	430	491	587	495
Pages of text per 1 000 members,	600	618	707	733	824	939	745
Total pages, all kinds	485	536	584	619	794*	784	662
Total pages per 1 000 members	832	913	1 020	1 051	1 332	1 254	995
GROSS COST:							
Total	$1 954.15	$2 194.26	$2 439.99	$2 706.05	$2 928.77	$3 266.65	$2 573.61
Per page	4.03	4.10	4.18	4.38	3.69	4.17	3.88
Per member	3.35	3.75	4.27	4.61	4.91	5.23	3.87
Per member per 1 000 pages	6.91	6.99	7.32	7.46	6.18	6.67	5.85
Per member per 1 000 pp. text,	9.71	10.31	10.60	10.72	10.00	8.91	7.81
NET COST:							
Total	$347.55	$332.90	$622.89	$770.62	$648.11	1 072.95	$387.96
Per page	.72	.62	1.07	1.25	.82	1.37	.58
Per member	.60	.57	1.09	1.31	1.09	1.72	.58
Per member per 1 000 pages	1.23	1.06	1.87	2.12	1.30	2.20	.88
Per member per 1 000 pp. text,	1.73	1.57	2.71	3.05	2.22	2.93	1.18

* Including General Index.

On motion of Mr. George A. Stacy the report was accepted and ordered placed on file.

Report of Finance Committee.

In the absence of Mr. Harry L. Thomas, Chairman, on account of illness, the report of the Finance Committee was read by Mr. Maybury as follows:

Boston, Mass., January 5, 1907.

We, the undersigned, members of the Finance Committee of the New England Water Works Association, met this day with your Secretary and Treasurer at the headquarters of the Association, and attended to the duties devolving upon us.

We examined the Secretary's book, verified additions, and found the total receipts \$5 274.18, as stated, to be correct. This amount he has turned over to the Treasurer, as his vouchers testify.

We have examined the Treasurer's accounts and found that his receipts from the Secretary agree with the amount as above stated. We have also examined the record of his payments, and find them correctly recorded, and properly certified and vouched for. These disbursements amount to \$4 845.14.

We find the invested funds in two savings banks to be \$2 721.16, and the cash on hand to be \$689.37, all as stated in the Treasurer's report, making a total of \$3 410.53 as a balance on hand for the beginning of the new year.

WILLIAM E. MAYBURY,
ARTHUR D. MARBLE,
Finance Committee.

On motion of Mr. R. P. C. Coggeshall the report was accepted and ordered to be printed.

Election of Officers.

(REPORT OF TELLERS OF ELECTION.)

Boston, Mass., January 9, 1907.

Mr. President, — The tellers appointed to canvass the ballots for the election of officers of the New England Water Works Association, for the year 1907, beg leave to report as follows:

Whole number of votes cast	207
Blank	6
Not properly endorsed	11
For President.	
John C. Whitney	196
William T. Sedgwick	1
For Vice-Presidents.	
M. N. Baker	197
J. M. Birmingham	196
George H. Snell	196
V. C. Hastings	196
George A. King	196
H. T. Sparks	196
For Secretary.	
Willard Kent	196
For Editor.	
Charles W. Sherman	197
For Advertising Agent.	
Robert J. Thomas	197
For Additional Members of Executive Committee.	
A. E. Martin	196
D. N. Tower	197
George W. Batchelder	197
C.-E. A. Winslow	1
For Finance Committee.	
Arthur D. Marble	198
William E. Maybury	198
George Cassell	197
For Treasurer.	
Lewis M. Bancroft	197

Rsepectfully submitted,

J. C. HAMMOND, Jr.,
ERMAN M. PECK,

Tellers.

The President announced the election of the various officers as shown by the return of the tellers, and said he was sure all the members desired to hear a word from the incoming president, Mr. Whitney. Mr. Whitney was greeted with loud applause and responded briefly, as follows:

Mr. President, — I thank you sincerely for your kind introduction, and I wish to assure you and all the members of the Association that with the assistance of all the members it is hoped that we may during the coming year maintain the high standard which has been set for us by previous presidents and officers, and that in the future the Association may continue to rank, as it does now, as the foremost society of its kind in the world. [Applause.]

The following applicants having been recommended by the Executive Committee, were elected to membership:

Chester H. Wells, Montclair, N. J., health officer; F. J. Hoxie, Phenix, R. I., engaged in general hydraulic work; Charles F. Eveleth, South Lincoln, Mass., mechanical engineer; Ralph E. Tarbett, Knoxville, Tenn., bacteriologist and engineer connected with the Knoxville Water Company.

The paper for the afternoon was read by Arthur N. French, superintendent of Water Company, Hyde Park, Mass., the subject being "Meter Registration." Messrs. J. A. Tilden, George A. Stacy, Edwin C. Brooks, George H. Snell, John C. Whitney, John H. Flynn, and J. C. Hammond, Jr., participated in the discussion which followed.

Dr. Langdon Frothingham, of the Harvard Medical School, gave a brief talk on Hydrophobia.

Adjourned.

February Meeting.

Hotel Brunswick,
Boston, February 13, 1907.

Mr. John C. Whitney, president, in the chair.

The following members and guests were present:

Honorary Members.

W. T. Sedgwick, F. W. Shepperd. — 2.

Members.

S. A. Agnew, C. H. Baldwin, L. M. Bancroft, W. T. Barnes, G. W. Batchelder, J. W. Blackmer, E. M. Blake, Dexter Brackett, E. C. Brooks, C. E. Childs, George Cassell, J. C. Chase, R. C. P. Coggeshall, M. F. Collins, W. R. Conard, J. H. Cook, J. W. Crawford, G. E. Crowell, John Doyle, B. R. Felton, C. R. Felton, J. N. Ferguson, F. F. Forbes, W. E. Foss, A. N. French, F. L. Fuller, A. S. Glover, F. E. Hall, J. O. Hall, E. A. W. Hammatt, G. W. Hawkes, H. G. Holden, J. L. Howard, H. R. Johnson, W. S. Johnson, E. W. Kent, Willard Kent, G. A. King, L. P. Kinnicutt, C. F. Knowlton, E. S. Larned, F. A. McInnes, Hugh McLean, H. V. Macksey, N. A. McMillen, D. E. Makepeace, F. E. Merrill, H. A. Miller, William Naylor, O. E. Parks, E. M. Peck, T. A. Peirce, J. H. Perkins, H. E. Royce, G. A. Sanborn, E. M. Shedd, C. W. Sherman, H. W. Sanderson, W. F. Sullivan, L. A. Taylor, R. J. Thomas, H. L. Thomas, W. H. Thomas, L. D. Thorpe, D. N. Tower, J. A. Tilden, W. H. Vaughn, R. S. Weston, J. C. Whitney, O. J. Whitney, G. E. Wilde, F. I. Winslow, G. E. Winslow. — 73.

Associates.

Builders Iron Foundry, by F. N. Connet; Coffin Valve Company, by H. L. Weston; The Fairbanks Company, by F. A. Leavitt; Hersey Manufacturing Company, by Albert S. Glover, J. A. Tilden, and W. A. Hersey; National Water Main Cleaning Company, by G. F. Whitney and A. P. Foster; International Steam Pump Company, by Samuel Harrison; Lead Lined Iron Pipe Company, by Thomas E. Dwyer; H. Mueller Manufacturing Company, by George A. Caldwell; National Meter Company, by C. H. Baldwin and J. G. Lufkin; Neptune Meter Company, by H. H. Kinsey; Platt Iron Works Company, by F. H. Hayes; Rensselaer Manufacturing Company, by C. L. Brown; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Union Water Meter Company, by F. L. Northrop; United States Cast Iron Pipe and Foundry Company, by Frank W. Nevins; R. D. Wood & Co., by Walter Wood and William F. Woodburn. — 21.

GUESTS.

Hon. Sidney B. Kane, Somerville, Mass.; Arthur C. King, Taunton, Mass.; W. E. Rawson, Uxbridge, Mass.; E. A. Blackmer, Plymouth, Mass.; John C. DeMello, Jr., general foreman, New Bedford, Mass.; M. F. Wright, Butler, Pa.; F. L. Clapp, Stoughton, Mass.; E. P. Byrne, city engineer, Medford, Mass.; H. E. Cowan, J. E. Taylor, William Lyman Underwood and A. G. Norton, Boston, Mass. — 12.

[Names counted twice — 4.]

The Secretary presented applications for membership, properly endorsed and recommended by the Executive Committee, from the following:

Charles Saville, Waban, Mass., assistant in the engineering department of the Massachusetts State Board of Health; Charles H. Rollins, Watertown, Mass., member of the Board of Water Commissioners, Watertown; George C. Bunker, Charleston, S. C., biologist and chemist, city of Charleston; Halsey French, New York, assistant engineer, Board of Water Supply, New York City; M. G. Hall, Centerville, Ia., superintendent of water works, Centerville.

On motion of Mr. Fuller the Secretary was instructed to cast one ballot in favor of the applicants named, and they were declared duly elected members of the Association.

The President presented a letter from an absent member, asking for experience with "Universal" cast-iron pipe. Messrs. John H. Cook, Charles W. Sherman, and Wm. R. Conard spoke upon this subject.

At this point the President called upon Mr. William R. Conard, of Burlington, N. J., who presented a paper entitled "Some Observations on Cast-Iron Pipe Specifications." The paper was discussed by Frank A. McInnes, Wm. E. Foss, John Doyle, Frank L. Fuller, and Walter Wood.

William Lyman Underwood, Esq., lecturer in the biological department of the Massachusetts Institute of Technology, gave a talk on the work of river drivers in the Maine woods, illustrated by stereopticon views.

Adjourned.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Wednesday, December 12, 1906, at 11.30 A.M.

Present: President Sedgwick and members, Charles W. Sherman, John C. Chase, Robert J. Thomas, Lewis M. Bancroft, Frank E. Merrill, and Willard Kent.

The following applications, twenty-three in number, were received and recommended for membership: John W. Maxcy, consulting engineer, Houston, Tex.; Arthur B. Cleaveland, United States Reclamation Service, Orman, S. D.; Albert L. Sawyer, water registrar, Haverhill, Mass.; E. F. Kitson, civil engineer, Norfolk, Va.; Nathaniel W. Hayden, president and manager, Windsor Water Company, Windsor, Conn.; Charles F. Breitzke, White Plains, N. Y.; Perkins Boynton, chemist, East Jersey Water Company, Little Falls, N. J.; William H. Beers, Jr., bacteriologist, Water Department, Columbia, N. C.; William L. Butcher, State House, Boston, Mass.; W. F. Currier, chemist, Philadelphia, Pa.; Herbert C. Emerson, M.D., Springfield, Mass.; Frederick W. Farrell, bacteriologist, Emerson Laboratory, Springfield, Mass.; Selskar M. Gunn, assistant bacteriologist, Iowa State Board of Health, Iowa City, Iowa; August E. Hansen, sanitary engineer, New York City; John H. McManus, assistant engineer, Board of Water Supply, City of New York, West Hurley, N. Y.; James A. Newlands, chemist, Connecticut State Board of Health, Middletown, Conn.; Burton G. Philbrick, water sanitarian with Lederle Laboratory, Brooklyn, N. Y.; Henry A. Pressey, Washington, D. C.; William J. Roberts, professor of civil engineering, State Agricultural College, Pullman, Wash.; Louis J. Richards, health officer, Board of Health, Elizabeth, N. J.; Luther R. Sawin, bacteriologist, New York Water Department, Mt. Kisco, N. Y.; L. R. Thurlow, health officer, Plainfield, N. J.; Alex. J. Taylor, engineer, Sewer Department, Wilmington, Del.

Voted: That three members and two associates dropped for non-payment of dues, who have since forwarded amount of dues, be reinstated to former membership.

Voted: That the following resolution be presented to the Association.

[Resolution printed on page 76.]

The place of the next Annual Convention was considered and the subject referred to a later meeting.

Adjourned.

Attest: Willard Kent, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Mass., January 9, 1907, at 11.30 A.M.

Present: President William T. Sedgwick, and members John C. Chase, James L. Tighe, Robert J. Thomas, Lewis M. Bancroft, Frank E. Merrill, Charles W. Sherman, George A. Stacy, and Willard Kent.

Four applications were received and recommended for membership, viz., Charles F. Eveleth, South Lincoln, Mass.; F. J. Hoxie, Phenix, R. I.; Chester H. Wells, Montclair, N. J.; Ralph E. Tarbett, Knoxville, Tenn.

Voted: That the subject of place of next annual convention be referred to the incoming Executive Committee with the recommendation that it be held within the limits of New England.

Voted: That the Secretary, Treasurer, Editor, and Advertising Agent be a Committee on Ladies' Day with full power to add to their number, and to act for the Executive Committee.

Adjourned.

Attest: Willard Kent, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Mass., January 24, 1907.

Present: President John C. Whitney, George A. King, D. N. Tower, George W. Batchelder, Robert J. Thomas, and Willard Kent.

The records of the last meeting of the Executive Committee were read and approved by vote.

On motion of Mr. Thomas, seconded by Mr. King, it was voted: That the annual custom of inviting the attendance of ladies at the February meeting be dispensed with for that occasion of the present year.

Voted: That the President and Secretary be a committee to arrange program of papers for the February meeting.

Voted: That the President and Secretary be a committee to provide music for the February meeting.

The June meeting, annual convention, and subject of a general circular relating to membership were discussed and referred to a later meeting.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Mass., February 13, 1907, at 11.30 A.M.

Present: President J. C. Whitney, and members Robert J. Thomas, L. M. Bancroft, D. N. Tower, George W. Batchelder, George A. King, Charles W. Sherman, and Willard Kent.

The records of the last meeting were read and approved.

Applications for membership were received from the following-named persons:

Charles Saville, engineering department, Massachusetts State Board of Health, Boston, Mass.; Charles H. Rollins, water commissioner, Watertown, Mass.; Halsey French, assistant engineer, Board of Water Supply, city of New York, N. Y.; George C. Bunker, biologist and chemist, city of Charleston, Charleston, S. C.; M. G. Hall, superintendent water works, Centerville, Ia.

These applications were considered, and it was voted to recommend them to the Association for election to membership. One other application was received and action thereon postponed.

On motion of Mr. Thomas, seconded by Mr. Bancroft, it was voted that the President and Secretary be, and hereby are, authorized to make the necessary arrangements for the June meeting of the Association.

A request from prominent members of the Association was received asking that the Treasurer of the Association be paid a

nominal salary of fifty dollars per annum; whereupon it was voted that the salary of the Treasurer for the year 1907 be fifty dollars.

On motion of Mr. Thomas, seconded by Mr. Batchelder, the salary of the Assistant Secretary for the year 1907 was increased to fifty dollars per month.

On motion of Mr. Batchelder, seconded by Mr. Thomas, the Secretary was authorized and instructed to investigate and report on the subject of a desirable place for holding the next annual convention.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XXI. June, 1907. No. 2.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

SOME NEW FACTS RELATING TO THE EFFECT OF METERS ON THE CONSUMPTION OF WATER.

BY WILLIAM S. JOHNSON, ASSISTANT ENGINEER, MASSACHUSETTS STATE BOARD OF HEALTH.

[*Read March 13, 1907.*]

For the past twenty years the advantages of selling water by meter have been much discussed, until now there are but few connected with the management of water works who question the desirability of having all services metered. There is much yet to be learned, however, as to the results to be accomplished. The enormous saving of water, and the consequent saving in expense which would be possible by the general use of meters, have been repeatedly demonstrated. The cities of Brockton, Fall River, and Providence, where meters have been in general use for many years, have been referred to time and time again as examples of what might be accomplished in other places. The English and German cities, with their still lower consumption, have also been frequently cited as examples of what ought to be accomplished in American cities.

During the past ten to twenty years great numbers of meters have been introduced, and now in many places the percentage of metered services is as great as in the cities which have so long served as examples, — but the predicted saving in water has not been accomplished. On the contrary, an examination of the figures of consumption shows that the rate of increase in the use of water in Brockton, Fall River, and Providence is greater than the rate

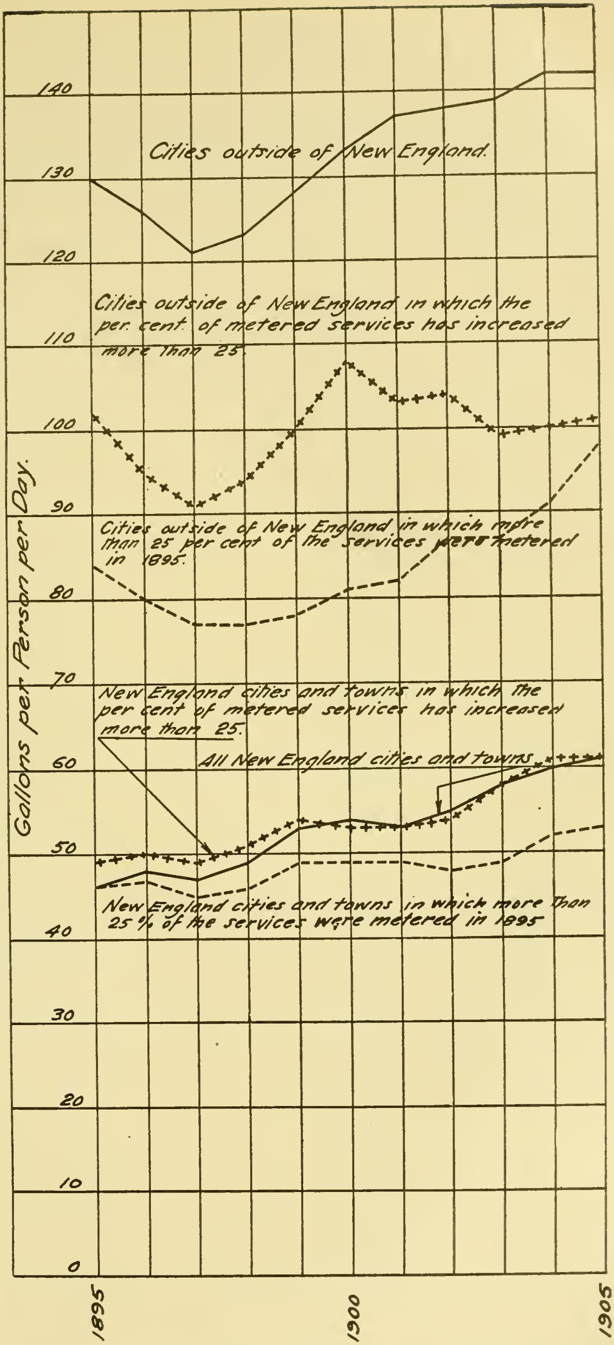
of decrease in many of the places where meters have recently been introduced, indicating that if the consumption in these other cities ever becomes the same as that of Brockton, Fall River, and Providence, the latter places are likely to meet the others half way.

Notwithstanding the great increase in the use of meters all over the country, the average quantity of water consumed per person is increasing at a rapid rate. The increase in the consumption of water during the past ten years is shown in the accompanying diagram, Fig. 1, which gives the average daily consumption in a large number of cities outside of New England and in the principal New England cities and towns. On the same diagram is shown the consumption of water in those places inside and outside of New England where, in 1895, at the beginning of the period, more than 25 per cent. of the services were metered, and the consumption in those places where the percentage of metered services has increased more than 25 during the ten years, — that is, where there has been a general introduction of meters.

We are struck, in the first place, by the great difference in the consumption of water in New England and in the cities outside of New England. This creditable showing we will explain as being due to the influence of the New England Water Works Association.

The startling feature of the diagram, however, is the apparent failure of meters to reduce the consumption of water, or even to check the increase. During this period of ten years there were installed in the places used in making these curves more than 250 000 meters. In the places used in making the averages outside of New England the percentage of metered services in 1895 was 13, while in 1905, at the end of the ten years, it had increased to 38. During this time there was an increase in the per capita consumption of water amounting to 11 gallons per day. In New England the percentage of metered services in 1895 was 40, increasing in the ten years to 60, while the consumption increased 15 gallons per person per day.

In those places outside of New England where more than 25 per cent. of the services were metered at the beginning of the period under consideration, the increase has been 14 gallons per day. In those places where there has been a very general introduction of meters during the period there has been a decrease of 1 gallon per



Gallons per Person per Day.
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1895
1900
1905
Cities outside of New England.
Cities outside of New England in which the per. cent. of metered services has increased more than 25.
Cities outside of New England in which more than 25 per cent of the services were metered in 1895.
New England cities and towns in which the per cent of metered services has increased more than 25.
All New England cities and towns
New England cities and towns in which more than 25 % of the services were metered in 1895

FIG. 1.

person per day. In New England the increase in consumption in those places which were very generally metered in 1895 has been kept down to 6 gallons per person per day, while in those places where the percentage of metered services has increased more than 25 during the ten years the increase has been 11 gallons per person per day.

In Table No. 1 are given statistics in relation to the consumption of water and the percentage of metered services, in 1905, in American cities having a population of more than 25 000. In Table No. 2 are given similar statistics for places in Massachusetts having a population of less than 25 000. The population of places in Massachusetts is the 1905 census population; outside of Massachusetts, where the latest available census is that of 1900, the population has been estimated by assuming that the rate of increase from 1900 to 1905 has been the same as that from 1890 to 1900. In practically all cases the population used is the total population of the city supplied, the only exception being where a large community is supplied outside of the city limits. This figure does not in all cases represent the actual population using the water, as in some of the places there is a considerable percentage of the population to which the public water supply is not available. On the other hand, in places used as summer resorts, and in cities which are business centers for the surrounding population, the number of people actually using the water is much larger than the census population. It is found that the estimates of the population actually supplied with water are in many cases very inaccurate, and better comparative results are obtained by taking the total population of the places supplied. The figures for consumption and for meters have been obtained in all cases either from printed reports or from the officials in charge of the water works.

TABLE No. 1.

Average Daily Consumption of Water and Percentage of Metered Services in 1905 in Cities having a Population of More than 25 000.

City.	Population.	Per Cent. Metered Services.	Consumption. (Gallons per Person per Day.)
Albany, N. Y.	93 765	15	211
Altoona, Pa.	43 291	3	112
Atlanta, Ga.	102 041	100	65
Atlantic City, N. J.	35 229	78	147
Auburn, N. Y.	32 588	6	172
Augusta, Ga.	42 511	0	150
Bay City, Mich.	27 523	33	122
Bayonne, N. J.	39 566	100	95
Boston, Mass.	595 380	5	151
Bridgeport, Conn.	82 061	5	210
Brockton, Mass.	47 794	90	38
Buffalo, N. Y.	400 748	3	324
Butte, Mont.	40 343	7	100
Cambridge, Mass.	97 434	19	92
Camden, N. J.	84 746	3	155
Canton, Ohio	32 906	2	125
Cedar Rapids, Ia.	29 474	40	83
Charleston, S. C.	56 233	2	57
Chelsea, Mass.	37 289	10	110
Chester, Pa.	40 869	20	75
Cincinnati, Ohio	340 399	12	130
Cleveland, Ohio	441 974	68	137
Columbus, Ohio	144 265	76	110
Covington, Ky.	45 721	100	51
Davenport, Ia.	39 445	50	81
Dayton, Ohio	97 389	70	70
Detroit, Mich.	325 614	9	188
Duluth, Minn.	62 896	41	77
Erie, Pa.	58 783	2	179
Evansville, Ind.	63 132	0	125
Everett, Mass.	29 111	2	89
Fall River, Mass.	105 762	97	42
Gloucester, Mass.	26 011	5	53
Grand Rapids, Mich.	101 211	29	123
Harrisburg, Pa.	55 557	73	171
Hartford, Conn.	93 160	98	66
Hoboken, N. J.	67 222	69	115
Holyoke, Mass.	49 934	8	120

City.	Population.	Per Cent. Metered Services.	Consumption. (Gallons per Person per Day.)
Indianapolis, Ind.	196 028	10	82
Jackson, Mich.	27 371	26	74
Jacksonville, Fla.	34 043	59	67
Johnstown, Pa.	43 000	1	159
Kansas City, Kan.	57 969	45	113
Kansas City, Mo.	179 270	38	73
Knoxville, Tenn.	37 688	36	67
La Crosse, Wis.	30 797	5	96
Lancaster, Pa.	46 183	20	130
Lawrence, Mass.	70 050	88	43
Lexington, Ky.	28 770	98	58
Lincoln, Neb.	32 677	100	40
Los Angeles, Cal.	128 521	31	120
Louisville, Ky.	226 531	8	81
Lowell, Mass.	94 889	69	58
Lynn and Saugus, Mass.	83 295	30	59
Malden, Mass.	38 037	78	53
McKeesport, Pa.	40 970	23	115
Manchester, N. H.	63 417	72	52
Memphis, Tenn.	121 232	20	100
Milwaukee, Wis.	325 735	80	91
Minneapolis, Minn.	221 708	47	76
Nashville, Tenn.	283 213	52	148
Newark, N. J.	278 190	44	117
New Bedford, Mass.	74 362	23	95
New Britain, Conn.	30 737	6	145
Newcastle, Pa.	36 708	1	94
New Haven, Conn.	121 391	3	168
Newport, Ky.	29 992	20	37
Newton, Mass.	36 827	86	58
Norfolk, Va.	52 500	0	125
Omaha, Neb.	83 607	59	110
Oshkosh, Wis.	31 008	15	76
Paterson, N. J.	118 583	37	87
Pawtucket, R. I.	79 400	81	104
Philadelphia, Pa.	1 417 063	1	230
Pittsburg, Pa.	363 116	0	210
Providence, R. I.	212 823	86	68
Quincy, Ill.	38 631	53	31
Quincy, Mass.	28 076	3	109
Racine, Wis.	33 146	51	90
Reading, Pa.	89 111	7	128

City.	Population.	Per Cent. Metered Services.	Consumption. (Gallons per Person per Day.)
Richmond, Va.	86 881	44	150
Rochester, N. Y.	176 964	41	88
Rockford, Ill.	34 784	19	95
Saginaw, Mich.	40 357	8	200
St. John, N. B.	45 432	3	143
St. Joseph, Mo.	128 306	20	58
St. Louis, Mo.	636 972	7	92
St. Paul, Minn.	178 020	38	56
Salt Lake City, Utah	57 875	2	309
San Antonio, Tex.	61 145	10	132
San Francisco, Cal.	364 674	21	96
Schenectady, N. Y.	37 572	0	99
Seattle, Wash.	99 588	12	100
Sioux City, Ia.	30 764	61	35
Somerville, Mass.	69 272	19	89
South Bend, Ind.	43 089	8	102
Springfield, Ohio	41 432	12	85
Superior, Wis.	40 645	31	57
Tacoma, Wash.	38 568	10	72
Taunton, Mass.	30 967	46	62
Terre Haute, Ind.	39 901	19	70
Toledo, Ohio	157 015	70	75
Toronto, Can.	270 000	4	93
Troy, N. Y.	60 500	4	248
Utica, N. Y.	62 569	98	59
Waltham, Mass.	26 282	10	79
Wilmington, Del.	84 046	21	102
Woonsocket, R. I.	31 888	85	37
Worcester, Mass.	128 135	95	75
Yonkers, N. Y.	55 879	99	115
York, Pa.	40 165	3	63

TABLE No. 2.

Average Daily Consumption of Water and Percentage of Metered Services in 1905 in Cities and Towns in Massachusetts having a Population of Less than 25 000.

City or Town.	Population.	Per Cent. Metered Services.	Consumption. (Gallons per Person per Day.)
Andover	6 632	78	68
Arlington	9 668	22	81
Attleboro	12 702	100	43
Avon	1 901	1	40
Ayer	2 386	55	53
Belmont	4 360	100	61
Beverly	15 223	3	87
Billerica	2 843	59	28
Braintree	6 879	37	87
Bridgewater and East Bridgewater	9 923	9	21
Brookline	23 436	93	95
Canton	4 702	47	63
Clinton	13 105	86	41
Danvers and Middleton	10 131	2	81
Dedham	7 774	37	135
Easton	4 909	43	24
Fairhaven	4 235	45	79
Falmouth	3 241	1	73
Foxboro	3 364	46	63
Franklin	5 244	2	44
Gardner	12 012	6	80
Groton	2 253	99	28
Hyde Park	14 510	34	77
Ipswich	5 205	30	26
Lexington	4 530	2	66
Manchester	2 618	100	94
Mansfield	4 245	33	49
Marlboro	14 073	59	41
Maynard	5 811	78	45
Medford	19 686	8	98
Melrose	14 295	3	112
Merrimac	1 884	100	28
Methuen	8 676	78	43
Middleboro	6 888	47	38
Milford and Hopedale	14 153	19	65
Milton	7 054	100	46
Montague	7 015	4	81

City or Town.	Population.	Per Cent. Metered Services.	Consumption. (Gallons per Person per Day.)
Nahant	922	18	149
Nantucket	2 930	0	56
Natick	9 609	58	56
Needham	4 284	95	66
Newburyport	14 675	2	51
North Andover	4 614	74	43
North Attleboro	7 878	100	40
Norwood	6 731	55	64
Orange	5 578	64	27
Peabody	13 098	4	133
Reading	5 682	89	28
Revere	12 659	4	80
Rockport	4 447	2	81
Shirley	1 692	99	13
Stoneham	6 332	2	81
Stoughton	5 959	59	64
Tisbury	1 120	1	63
Walpole	4 003	47	86
Ware	8 594	100	41
Wareham	3 660	0	10
Watertown	11 258	94	70
Webster	10 018	48	34
Wellesley	6 189	100	47
Weston	2 091	81	31
Whitman	6 521	54	25
Winchendon	5 933	97	18
Winthrop	7 034	2	114
Woburn	14 402	2	103

In order to show the relation between the percentage of metered services and the consumption, Tables No. 3 and No. 4 are presented, giving the average consumption in those places having certain percentages of services metered.

TABLE No. 3.

AVERAGE CONSUMPTION OF WATER PER PERSON IN 1905 IN CITIES HAVING A POPULATION OF MORE THAN 25 000, ARRANGED IN GROUPS ACCORDING TO THE PERCENTAGE OF SERVICES WHICH ARE PROVIDED WITH METERS.

	Gallons per Day.
Average of 34 cities in which not more than 10 per cent. of the services are metered	146
Average of 23 cities in which more than 10 per cent. but less than 25 per cent. of the services are metered	97
Average of 18 cities in which more than 25 per cent. but less than 50 per cent. of the services are metered	89
Average of 14 cities in which more than 50 per cent. but less than 75 per cent. of the services are metered	89
Average of 19 cities in which more than 75 per cent. of the services are metered	72

TABLE No. 4.

AVERAGE CONSUMPTION OF WATER PER PERSON IN 1905 IN CITIES AND TOWNS IN MASSACHUSETTS HAVING A POPULATION OF LESS THAN 25 000, ARRANGED IN GROUPS ACCORDING TO THE PERCENTAGE OF SERVICES WHICH ARE PROVIDED WITH METERS.

	Gallons per Day.
Average of 26 cities and towns in which not more than 25 per cent. of the services are metered	77
Average of 12 cities and towns in which more than 25 per cent. but less than 50 per cent. of the services are metered	63
Average of 9 cities and towns in which more than 50 per cent. but less than 75 per cent. of the services are metered	45
Average of 22 cities and towns in which more than 75 per cent. of the services are metered	48

These tables show that there is a marked difference in the consumption of water in the places which are generally metered and in those places which are not metered, but they also show that the consumption of water in the larger cities, even in places which are generally provided with meters, is much in excess of that in Brockton and Fall River.

The foregoing tables show the consumption in 1905 as compared with the number of meters in use at that time, and include places which have been thoroughly metered for a long period. In many places meters have been generally introduced within a few years, and in order to show the immediate effect of the introduction of

meters Table No. 5 has been prepared, which gives the increase or decrease in the consumption of water as compared with the increase in the percentage of metered services in the period from 1890 to 1905, and in the five years from 1900 to 1905.

TABLE No. 5.

INCREASE IN THE CONSUMPTION OF WATER IN CITIES AND TOWNS DURING THE PERIODS FROM 1890 TO 1905, AND FROM 1900 TO 1905, COMPARED WITH THE INCREASE IN THE PERCENTAGE OF METERED SERVICES DURING THE SAME PERIODS.

Increase in Percentage of Metered Services.	1890 — 1905.		1900 — 1905.	
	Number of Places.	Increase in Consumption. Gallons per Person per Day.	Number of Places.	Increase in Consumption. Gallons per Person per Day.
Less than 10	27	36	95	7
10–25	25	10	33	1
25–50	16	9	12	6*
More than 50	11	14	4	17*

* Decrease.

This table shows the effect of the introduction of a large number of meters within a short period. As would naturally be expected, the immediate effect is a reduction in the quantity of water used; but while the introduction of more than 25 per cent. of metered services within five years reduces the consumption, the introduction of the same number of meters in a period of fifteen years does not prevent a substantial increase in the consumption. In other words, it would appear that after a certain amount of waste has been checked, the increase in the consumption continues notwithstanding the use of meters.

The accompanying diagrams, Figs. 2 to 13, show graphically the relation between the percentage of metered services and the per capita consumption of water in several typical cities. In Figs. 2 to 7 will be seen the increase in consumption in cities which are thoroughly metered, the increase in all cases being very substantial. This increase may be called the normal increase in the consumption with all reasonable precautions taken against waste.

In the case of Richmond, Fig. 8, is shown the effect of the intro-

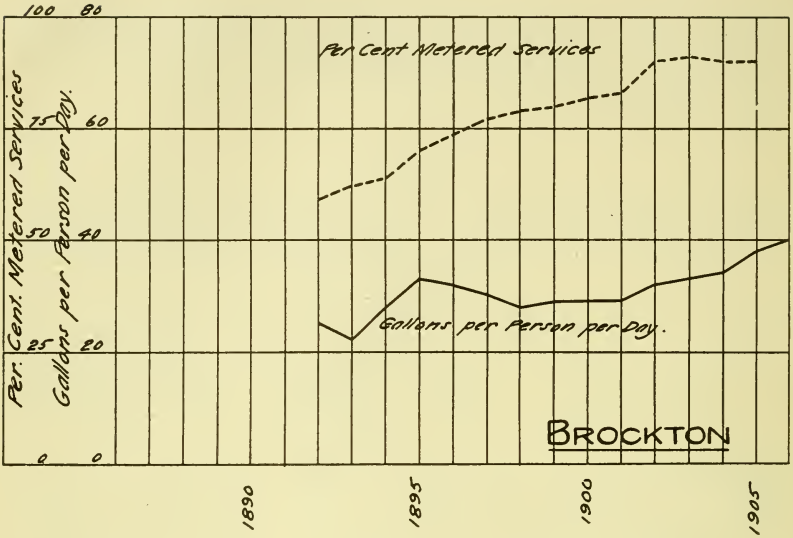

100
80
75
60
50
40
25
20
0
0
Per. Cent. Metered Services
Gallons per Person per Day.
Per Cent Metered Services
Gallons per Person per Day.
BROCKTON
1890
1895
1900
1905

FIG. 2.

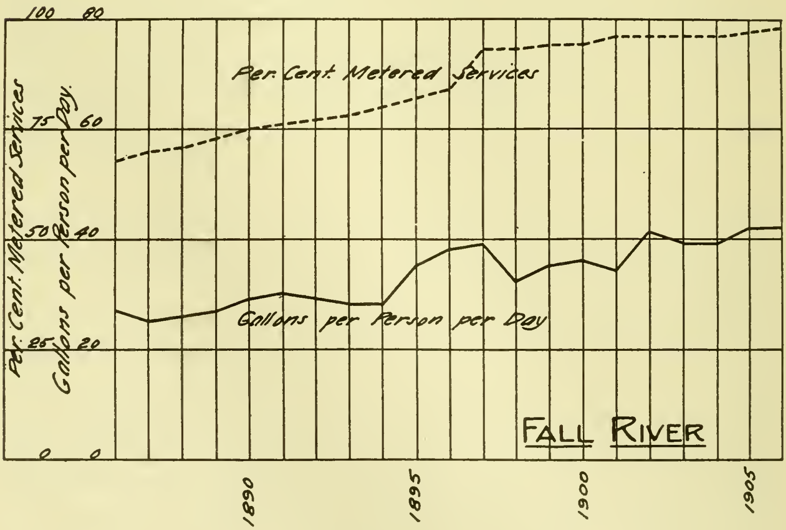

100
80
75
60
50
40
25
20
0
0
Per. Cent. Metered Services
Gallons per Person per Day.
Per. Cent. Metered Services
Gallons per Person per Day
FALL RIVER
1890
1895
1900
1905

FIG. 3.

duction of meters on an abnormally large consumption, and this is a typical diagram. The immediate effect of the introduction of meters in such a place is to make a great reduction in the quantity of water used. The reduction continues for a few years until the principal sources of waste are discontinued, or possibly until the vigilance of the water department is somewhat abated, and then

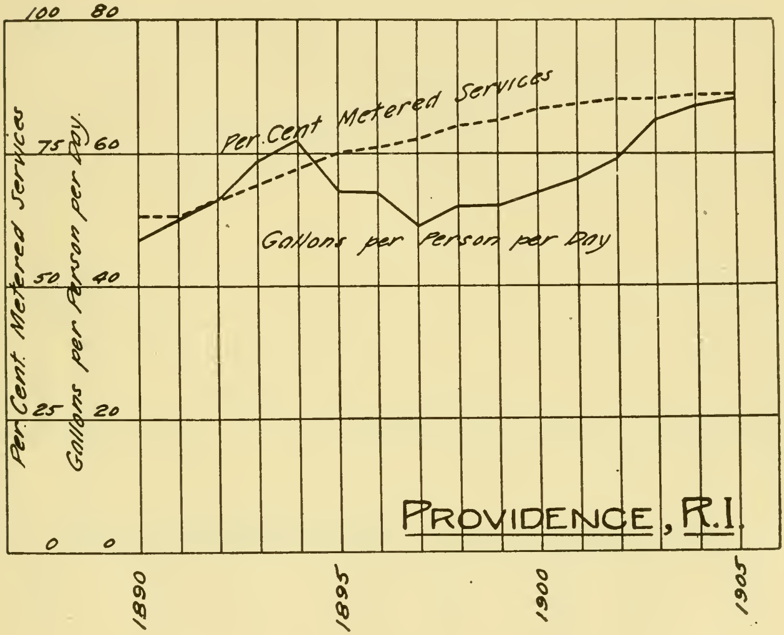


FIG. 4.

the increase in consumption again begins at substantially the same rate as before meters were introduced.

In Needham and Attleboro, Figs. 9 and 10, the introduction of meters appears to have failed to check the increase in the consumption.

The last three diagrams, Figs. 11, 12, and 13, show cases where the effect of meters may be overestimated, as there are other conditions which affect the quantity of water consumed. It is well

known that where the water supply is of poor quality a much greater quantity is used than where the water is clear and colorless, and this is especially the case where the water contains an excessive amount of iron or large numbers of organisms, as faucets are allowed to run for a long time in an attempt to make the water run clear. In the places represented in these diagrams water of poor

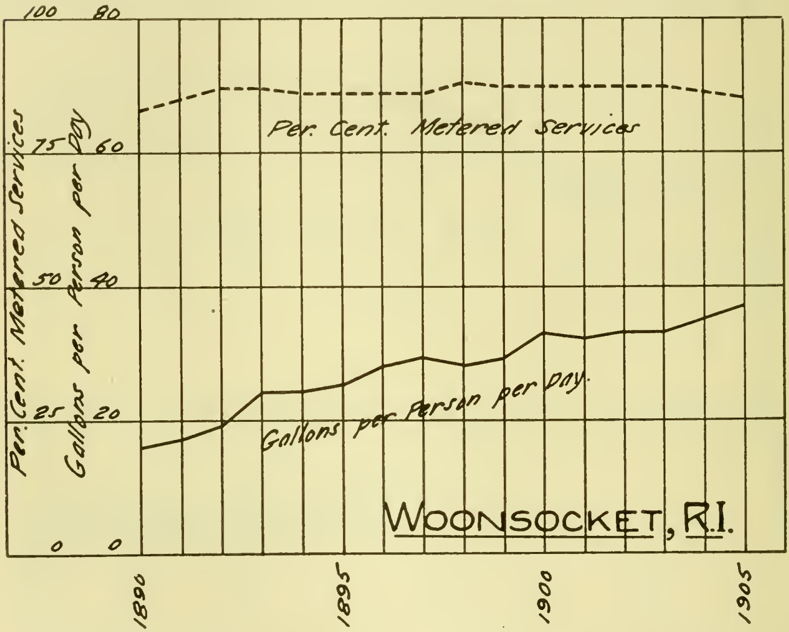


FIG. 5.

quality was supplied up to the time when the reduction in the consumption began. In the case of Reading the water contained such large quantities of iron as to make it practically unfit for any domestic purpose. After the construction of a filter to remove the iron the consumption of water was reduced very materially, and the greatest reduction occurred the year before the general introduction of meters. In Lowell and Lawrence meters were being rapidly introduced for many years before the reduction in

consumption began, and this reduction occurred immediately after the introduction of a better water supply.

It is very dangerous to draw conclusions from individual cases without a knowledge of all of the conditions, but the places in-

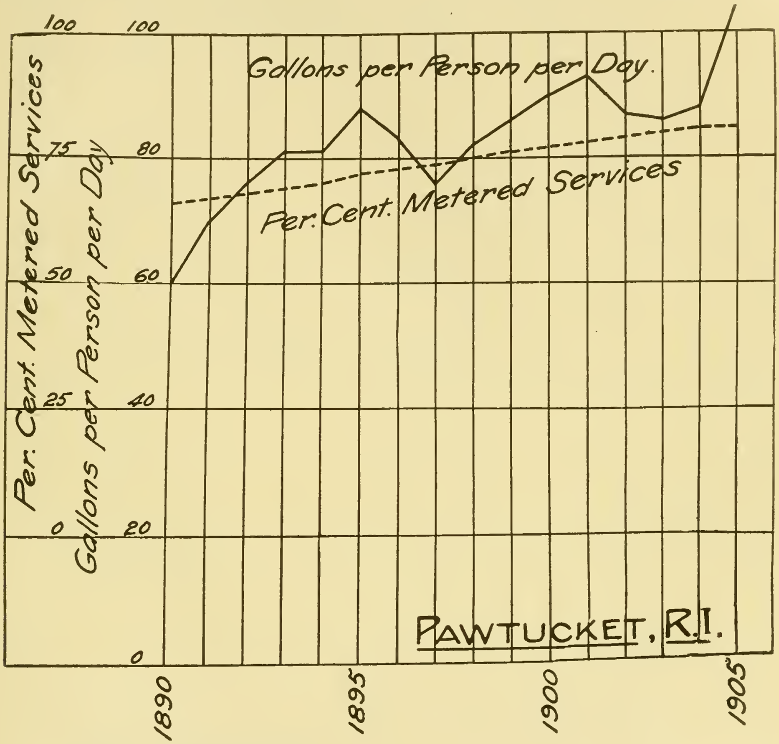


FIG. 6.

cluded in these diagrams are selected because they are typical of a large number of places.

Enough has been shown to indicate that the introduction of meters in places where the consumption of water has been large has not, in most cases, produced the results which have been anticipated. What, then, has been accomplished by meters, and what effect are they likely to have on the consumption of water in the future?

In the consideration of what meters will accomplish, it is convenient to divide the use and waste of water into the following classes:

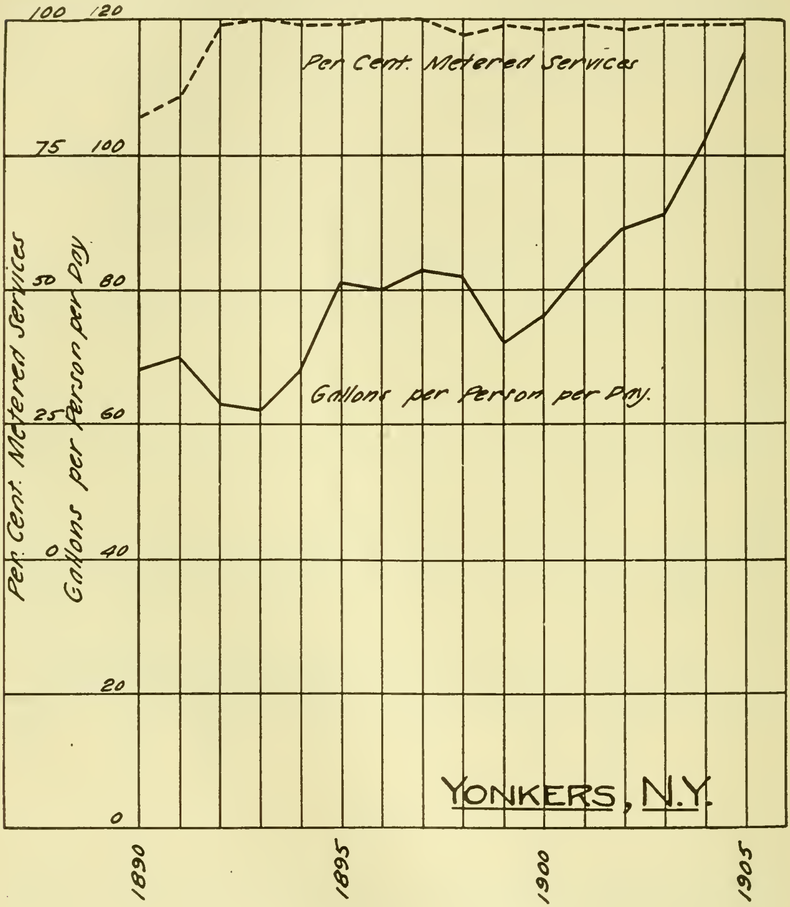
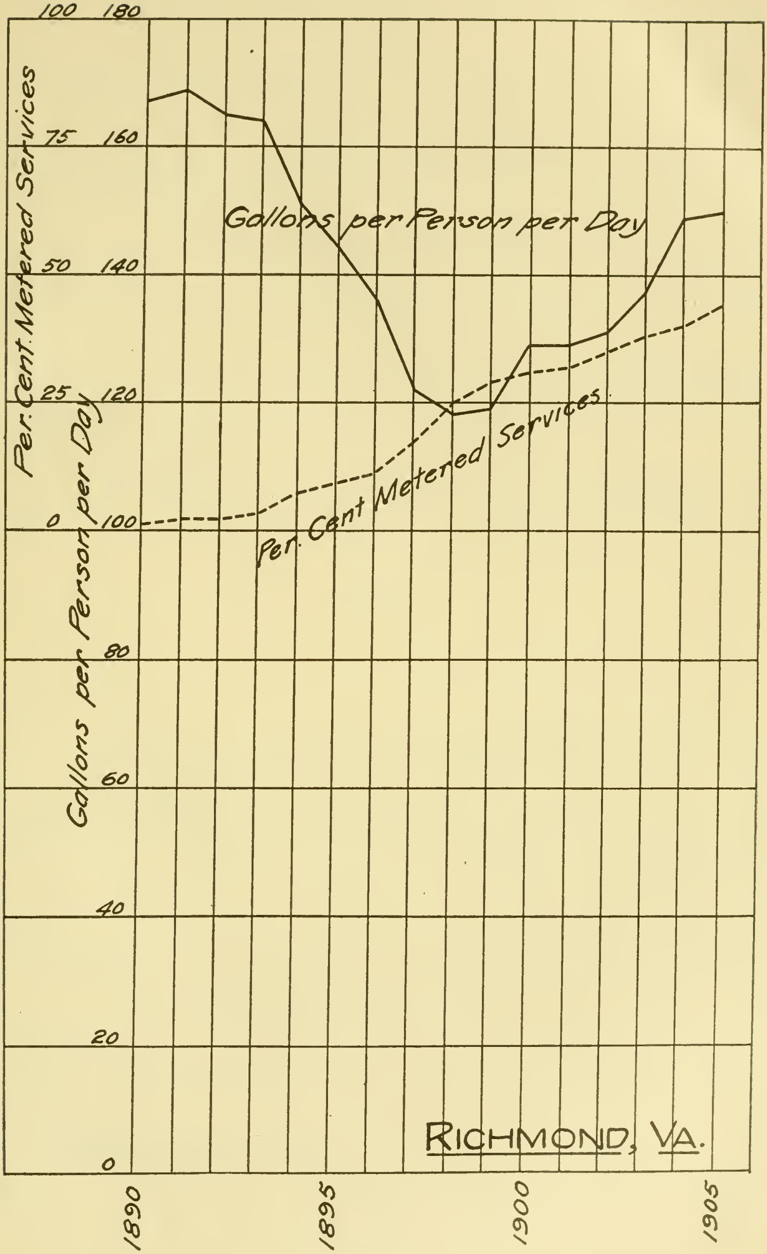


FIG. 7.

1. Water used or wasted in houses.
2. Water used in factories and for mechanical purposes.
3. Water used for public purposes, such as watering streets, supplying drinking fountains, etc.
4. Leakage from street mains, distributing reservoirs, and service pipes.



100
180
75
160
50
140
25
120
0
100
80
60
40
20
0
Per. Cent. Metered Services
Gallons per Person per Day
Gallons per Person per Day
Per. Cent Metered Services
RICHMOND, VA.
1890
1895
1900
1905

FIG. 8.

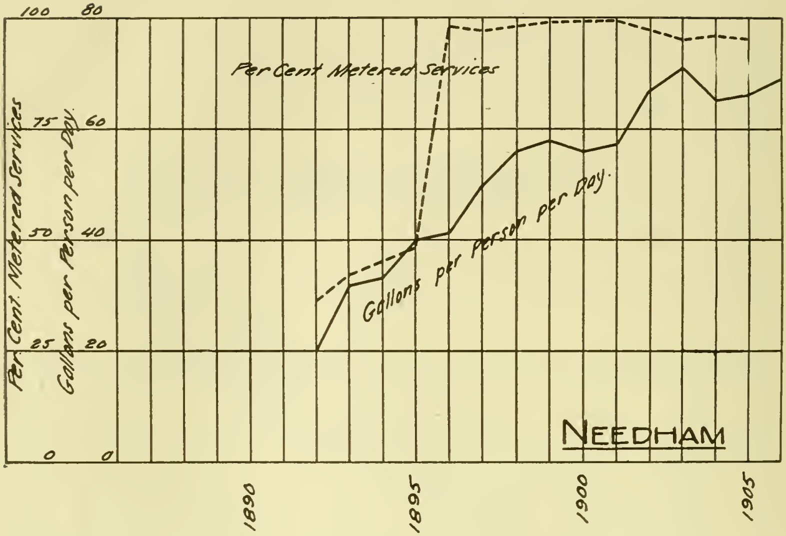

100 80
75 60
50 40
25 20
0 0
Per Cent. Metered Services
Gallons per Person per Day.
Per Cent Metered Services
Gallons per Person per Day.
NEEDHAM
1890
1895
1900
1905

FIG. 9.

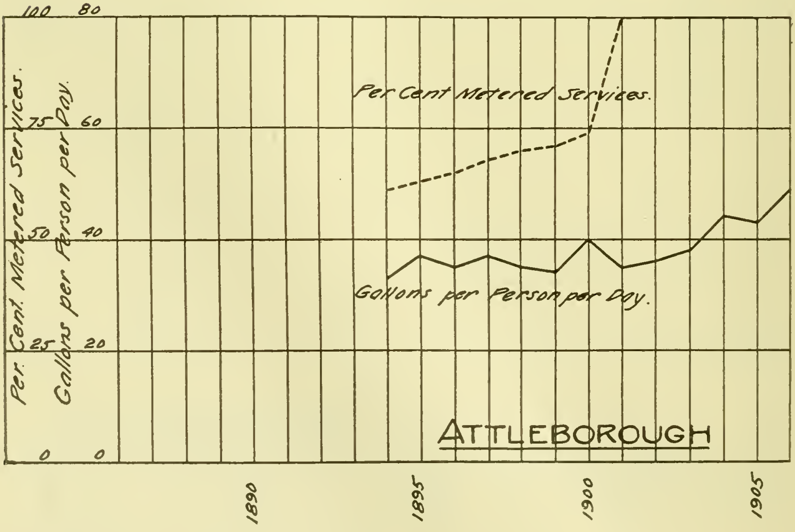

100 80
75 60
50 40
25 20
0 0
Per. Cent. Metered Services.
Gallons per Person per Day.
Per Cent Metered Services.
Gallons per Person per Day.
ATTLEBOROUGH
1890
1895
1900
1905

FIG. 10.

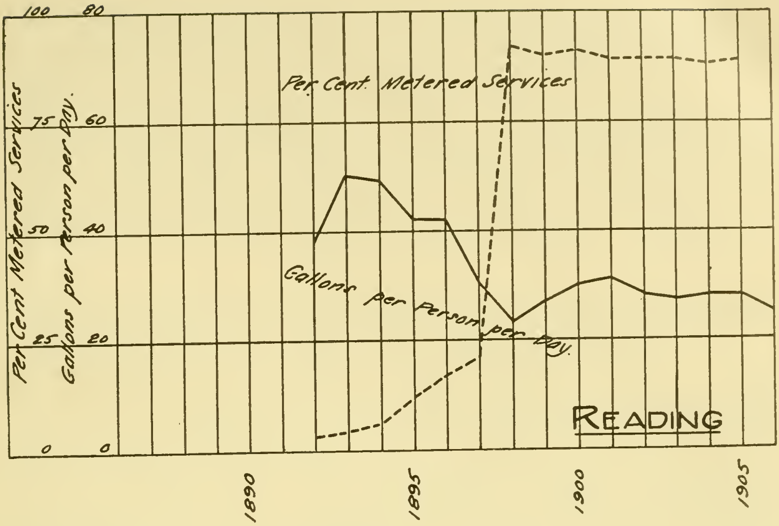

100 80
75 60
50 40
25 20
0 0
Per Cent Metered Services
Gallons per Person per Day.
Per Cent. Metered Services
Gallons per Person per Day.
READING
1890
1895
1900
1905

FIG. 11.


100 80
75 60
50 40
25 20
0 0
Per Cent. Metered Services.
Gallons per Person per Day.
Gallons per Person per Day
Per Cent Metered Services
LOWELL
1890
1895
1900
1905

FIG. 12.

The use and waste of water in houses includes water which leaks from defective pipes and fixtures or which is wasted by allowing the water to run continuously, and water which is intentionally drawn from the faucets or other fixtures. The quantity lost through defective plumbing fixtures is, in many cases, very large, and it is here that the house meter is most useful. Unfortunately, however, statistics in regard to the quantity actually lost cannot be obtained. Efficient inspection will do much toward preventing

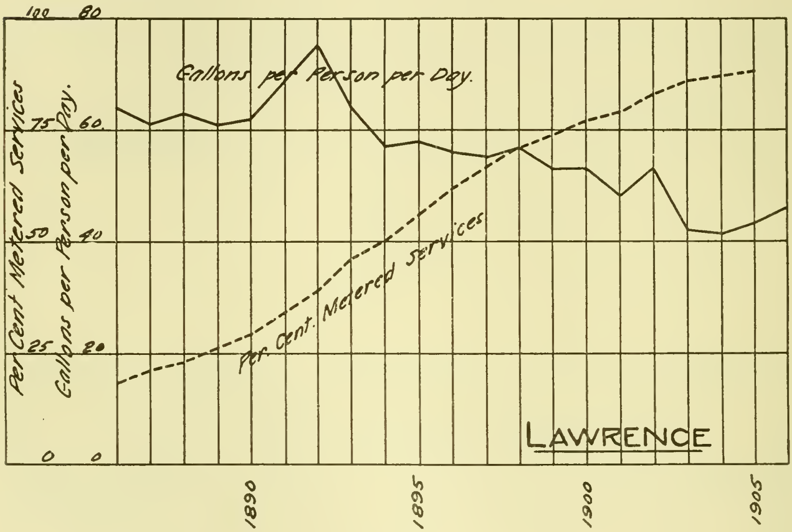


FIG. 13.

waste in this way, but increased water bills caused by leaky plumbing are more effective than the most efficient inspection.

The quantity of water wasted by intentionally leaving faucets open is probably much smaller than is generally believed. The line between the legitimate use and the waste of water is not well defined, but water which is intentionally drawn from the faucets or other fixtures, whether or not more than actually necessary for the purposes for which it is drawn, may be said to be legitimately used. Under this definition the water which is used by allowing the faucets to run during cold nights to prevent freezing may be

classed under legitimate use. Investigations have shown that the actual quantity of water consumed in this way is comparatively small.

The following table gives the relation which the consumption in each month bears to the average consumption, together with the average rainfall and temperature in Massachusetts:

TABLE No. 6.

PERCENTAGE WHICH THE CONSUMPTION DURING EACH MONTH IS OF THE AVERAGE MONTHLY CONSUMPTION, TOGETHER WITH THE AVERAGE RAINFALL AND TEMPERATURE. (MASSACHUSETTS.)

Average of Ten Years from 1896 to 1905.

Month.	Per Cent. of Average Consumption.	Rainfall. (Inches.)	Temperature. (Degrees F.)
January	90	3.68	23.9
February	92	3.98	24.3
March	89	4.77	34.9
April	87	3.86	45.6
May	100	3.18	57.2
June	113	3.60	64.5
July	124	3.85	70.7
August	118	3.97	67.6
September	108	4.12	61.4
October	96	3.35	50.9
November	90	3.34	38.7
December	92	3.74	27.7

It will be seen that the difference between the consumption during the coldest months and the consumption during April, — the month of minimum consumption, — is only 5 per cent. This excess of consumption generally comes in a few days, but it comes at a time when the sources of supply are least affected by a great draft upon them, except in cases where water is drawn from large storage reservoirs, and it comes at a time when the consumption is naturally small, so that the plant will not be called upon to do an excessive amount of work, as compared with the work required during the summer months. The cost of supplying the extra

water required to keep the faucets from freezing is insignificant as compared with the cost of repairing frozen pipes, and while I would not advocate putting plumbing in a house in such a manner that it would be necessary to allow the water to run during cold weather, I cannot criticise very severely the householder who uses a few cents worth of water to save a plumber's bill of many dollars, and if the water is sold at meter rates such use of the water is certainly legitimate. The quantity of water used for this purpose is undoubtedly greater than is necessary, and is reduced by the introduction of meters, but the total saving is in most cases an exceedingly small proportion of the yearly consumption.

The quantity of water actually used for strictly domestic purposes is increasing at a very rapid rate. In the first place, the number of fixtures in houses is increasing. This is especially noticeable in the less expensive houses, which now contain many plumbing fixtures where formerly a single faucet was all that would be provided. Not only is the number of fixtures increasing rapidly, but the quantity of water used by each fixture is increasing. The modern sinks, water-closets, and bath-tubs require very large quantities of water. The faucets and pipes are made of such a size that they deliver water much more freely, which tends to increase the quantity used. In the State House at Boston the water-closets are so constructed that every time a closet is flushed 5 gallons of water enter the sewer. The wash-basins are of such a shape and size that in order to obtain a sufficient depth of water for washing the hands it is necessary to draw from 1½ to 2 gallons, and the basins hold 2½ gallons when full to the overflow. It is easy to figure that a person of ordinary cleanliness, with such plumbing fixtures as those in the State House, and with a modern large-sized bath-tub, will use a much larger quantity of water than that allowed the average person in many of the estimates which are made of the quantity of water necessary for a water supply. The American people are undoubtedly wasteful, not only of water, but of all other commodities, and it is safe to say that they will not submit to being restricted in the use of water for which they are willing to pay any more than in the use of food supply or of fuel, of which large quantities are wasted.

Many interesting facts have been published from time to time

in regard to the actual consumption of water in houses of different classes, as indicated by meter readings. Table No. 7 gives a summary of recent studies made in Fall River, — a manufacturing city where the consumption is 42 gallons per person per day, — and in Needham,— a residential town where the consumption is 79 gallons per day. Meters are very generally used in both places.

TABLE No. 7.

Statistics in Regard to the Consumption of Water in Houses of Different Classes in Fall River and Needham, Mass.

(Fall River.)

Class.	Number of Persons.	Gallons per Person per Day.	Persons per Water-Closet.	Persons per Bath-Tub.
A	44	49.6	1.6	2.6
B	160	23.7	2.5	4.3
C	550	13.2	3.9	8.3
D	792	12.2	7.6	*

(Needham.)

Class.	Number of Persons.	Gallons per Person per Day.	Persons per Water-Closet.	Persons per Bath-Tub.
A	68	71	3	3
B	73	20	5	5
C	131	9	9	10

* No bath-tubs.

In each case class A represents the most expensive houses, surrounded by lawns, and the last class includes some of the cheapest tenement houses. When it is considered that a large proportion of the houses in Fall River would be included in the last classes, while a comparatively small proportion is included in the last class in Needham, a portion of the difference in the consumption of water in these two places is accounted for.

To further illustrate the difference in the consumption of water in different classes of cities or towns, Table No. 8, which gives the average consumption of water in the cities and towns of Massachusetts, arranged in groups, is introduced.

TABLE No. 8.

Average Consumption of Water during Each Month in 1905 in Cities and Towns Arranged in Groups.

(Gallons per Person per Day.)

Month.	Boston.	Metropolitan District.	Average of 23 Suburban Cities and Towns.	Average of 14 Large Manufacturing Cities.	Average of 37 Small Cities and Towns.	Average of 12 Summer Resorts.
January ..	165	137	77	70	48	67
February .	175	147	85	74	53	75
March	152	127	77	69	50	65
April	140	117	73	65	46	65
May	144	121	79	68	52	89
June	146	123	79	70	53	109
July	151	131	88	72	58	150
August ...	148	127	79	69	56	131
September	147	126	75	65	50	101
October...	145	124	73	65	47	74
November.	144	122	70	64	46	61
December .	153	129	71	64	45	65
Year	151	128	77	68	50	88

This table shows not only the difference in the average consumption for the year in the different classes of cities and towns, but it shows the monthly differences in the use of water. In the case of the summer resorts, the summer consumption is large for obvious reasons. In the suburban places there is a great quantity of water used on lawns and gardens, which increases the summer consumption.

These tables serve to show that there are natural differences in the use of water which cannot be overcome by the introduction of meters, and that it is impossible to produce, in places like Needham, conditions like those in Fall River.

The quantity of water used in manufacturing differs greatly in different places, due to differences in the character and location of the town, the character of the factories, and the attitude which the town takes in regard to supplying water to the factories. The quantity used in factories for sinks and water-closets has been determined from a study of the meter readings in a large number

of factories in various cities, and is found to be fairly uniform in places where water used for this purpose is metered. Table No. 9 gives characteristic results from several factories examined.

TABLE No. 9.

WATER USED FOR SINKS AND WATER-CLOSETS IN FACTORIES WHERE ALL WATER IS METERED.

Number of Operatives.	Water Used. Gallons per Day per Operative.
600	2.3
2 093	5.9
100	3.6
1 500	3.1
270	6.1
50	3.2
275	5.4
400	2.3
220	5.9
120	2.1
1 000	5.6
545	2.9
769	2.2
609	3.6
50	6.1
150	4.3
525	6.6
510	3.0
130	4.0
125	2.3
Average,	4.0

The figures in the above table are for factories where the water used is paid for by measurement. The quantity used in many factories where the water is not measured is very much in excess of these amounts, as the water is often allowed to run continuously through both sinks and water-closets.

The quantity of water used in manufacturing processes or for mechanical purposes is frequently large in comparison with the quantity used for strictly domestic purposes, and in some places the use of water by factories is encouraged by making only nominal charges for it, the smaller consumers being in such cases taxed for the support of the factories. There is now being constructed

for a New England city an expensive plant for the purification of 300 gallons per person per day, a large proportion of this water going to the numerous factories located in the city, but the city officials in this case prefer to incur the expense of a large purification plant rather than curtail the use of water in the factories.

In some cases factories are so situated that an independent water supply cannot be obtained, and it is necessary to obtain water from the public works. The quantity used in manufacturing processes can be ascertained only by investigation in each particular case, and before attempting to prophesy what can be done by domestic meters in any town, it is necessary to know how much water is used by factories and for mechanical purposes.

Table No. 10 contains interesting statistics in regard to the largest metered consumers of water in various cities and towns.

TABLE No. 10.

USE OF WATER BY LARGEST CONSUMERS.

City or Town. (Massachusetts.)	Average Daily Consumption.		Quantity Used by Ten Largest Consumers.		
	Gallons per Day.	Gallons per Person per Day.	Gallons per Day.	Gallons per Person per Day.	Per Cent. of Total Consumption.
Andover	484 000	73	61 800	9	12.8
Attleboro	641 000	49	62 100	5	9.7
Brockton	1 993 000	40	166 100	3	8.3
Clinton	543 000	42	146 100	11	26.9
Fall River ...	4 478 000	42	444 300	4	9.9
Lawrence	3 308 000	46	335 800	5	10.2
Lowell	5 084 000	54	189 900	2	3.7
Malden	2 000 000	51	113 100	3	5.7
Marlboro	554 000	39	98 600	7	17.8
Middleboro	263 000	38	77 000	11	29.0
Newton	2 223 000	59	115 100	3	5.2
North Andover	202 000	43	27 400	6	13.6
North Attleboro	282 000	35	15 000	2	5.3
Norwood	403 000	58	108 600*	16*	26.9*
Reading	147 000	25	7 300	1	5.0
Taunton	1 915 000	62	388 900	13	20.3
Watertown ...	771 000	67	134 700	12	17.5
Wellesley	273 000	43	24 300	4	8.9
Worcester	9 193 000	71	1 511 700	12	16.4

* Eight largest consumers.

The quantity used by ten of the largest consumers of water is given, together with the increase in the average per capita consumption due to these ten consumers. Upon studying this table some of the inequalities in the figures in consumption are explained. If the amount consumed by the ten largest consumers is deducted from the total consumption, the amount used by the remaining consumers in the different cities and towns is much more uniform. If 20 consumers had been included there would be a still greater similarity in the quantity used by the remaining consumers. It will be seen that in those places which have been so frequently referred to, namely Brockton and Fall River, there are no very large consumers of water. In Brockton the shoe shops use but little water, and in Fall River the water used by the factories is obtained from independent sources. In places having a large per capita consumption of water, the amount used by the large consumers is a very substantial proportion of the total consumption. In all of the places included in the table water is paid for at meter rates, and it is evident that the further introduction of meters in places like Norwood, Taunton, and Watertown is not likely to reduce the consumption to that of North Attleboro and Reading.

Very little is known about the quantity of water used for public purposes. Even where practically all of the domestic services are metered, it is not common to measure the quantity of water used for street watering, supplying drinking fountains, and other similar purposes. The quantity used for such purposes is undoubtedly very large, and in many places unnecessarily large, but in general the quantity so used will not be affected by the general use of meters. Statistics obtained from several places in Massachusetts indicate that the quantity used for such purposes amounts to from 4 to 10 gallons per person per day.

The quantity of water lost by leakage from street mains, distributing reservoirs, service pipes, etc., is in many cases very excessive. The best estimate of this quantity is obtained from a comparison of the quantity of water drawn from the sources of supply with the quantity of water passed through meters in those places where practically all of the services are supplied with meters. Statistics for a number of places where records of this kind are available are given in Table No. 11.

TABLE No. 11.

Table Showing the Relation between the Quantity of Water Passed through Meters and the Total Quantity of Water Pumped in 1905 in Certain Cities and Towns in which the Services are Largely Provided with Meters.

City or Town (in Massachusetts when not otherwise indicated).	Per Cent. of Metered Services.	Total Quantity of Water Pumped in 1905. (Gallons.)	Quantity Passed through Meters. (Gallons.)	Per Cent. Passed through Meters.
Attleboro	100	200 753 000	94 728 000	47
North Attleboro ...	100	150 473 000	51 948 000	45
Wellesley	100	105 503 000	55 014 000	52
Ware	100	128 539 000	84 121 000	65
Yonkers, N. Y.	99	2 334 459 000	1 100 884 000	47
Fall River	97	1 608 652 000	956 168 000	59
Winchendon	97	35 446 000	16 154 000	45
Madison, Wis.	97	537 187 000	165 951 000	31
Needham	95	103 487 000	26 012 000	25
Worcester.........	95	3 517 397 000	1 881 254 000	53
Watertown........	94	287 605 000	153 676 000	53
Brockton	90	732 083 000	416 188 000	57
Lawrence	88	1 094 881 000	570 736 000	52
Clinton	86	197 938 000	104 277 000	53
Newton...........	86	785 222 000	510 000 000	65
Burlington, Vt. ...	79	385 443 000	208 139 000	54
Andover	78	164 151 000	54 423 000	33
Malden	78	737 127 000	289 262 000	39
North Andover	74	72 170 000	23 557 000	33
Lowell............	69	1 998 929 000	801 401 000	40
Cleveland, Ohio ...	68	22 053 442 000	10 780 154 000	49

It will be seen from this table that practically half of the water which is drawn from the sources is unaccounted for by the meters. This discrepancy is doubtless due in part to errors in the registration of the meters and in part to errors in the rating of the pumps where the quantity drawn from the sources is determined by the pumping records. There is also, in many of these places, a large quantity of water which is used for street sprinkling and for drinking fountains and similar public uses which is not measured, but after allowance has been made for all of these errors and uses there still remains a large quantity of water which is not accounted for which must be attributed to leakage in the system. To whatever this discrepancy between the quantity drawn from the sources

and the quantity actually used is due, — whether to the use of the water in the streets or to leakage, — it is evident that it is not affected by the use of meters. The quantity thus unaccounted for in the places included in the table amounts to a per capita consumption of from 14 to 70 gallons per day.

In practically all of the places included in the foregoing tables the water supply is obtained by pumping, as it is, unfortunately, only in such places, as a rule, that any knowledge can be obtained as to the quantity of water used. In only a few cases where water is supplied by gravity are there any means of measuring the water, and it is safe to say that the consumption, in places where nothing is known of the quantity of water consumed, is much greater than in those places where such records are kept. It is undoubtedly a fact that in some cases almost as much would be accomplished by the introduction of large meters on the main lines of supply as by the introduction of house meters. In this connection I can do no better than to quote from a statement made in 1900 by Mr. X. H. Goodnough, chief engineer of the Massachusetts State Board of Health:

"In cases where water is supplied by gravity it is generally considered unnecessary and often a waste of money to attempt to make any continuous and approximately correct record of the quantity of water used. There is no doubt, however, that in many such cases a knowledge of the excessive use of water would lead to a great reduction in waste and to a saving in the cost of construction and operation of the works far greater than the expense of making the necessary measurements."

A good illustration of the value of a knowledge of the quantity of water used is found in the experience of the city of Holyoke, where meters were recently introduced on the main lines of supply. It was found upon reading these meters that the average daily consumption of water in the city was 144 gallons per person. Upon making this discovery steps were immediately taken to ascertain where the water was going, and by vigilant inspection during a period of a few months the consumption was reduced to 103 gallons per day, the actual saving of water amounting to over 2 000 000 gallons per day. During the investigations which were made it was found that large quantities of water were being

stolen, and it is said that the revenue has been increased very materially by these discoveries, directly attributable to the introduction of large meters on the supply lines.

From a consideration of the foregoing facts it is evident that disappointment is inevitable in the case of many cities and towns where meters are being introduced. In the case of one town which has recently come to my notice, the population is about 10 000 and the per capita consumption is from 96 gallons per day in winter to 128 gallons per day in summer, and the general introduction of meters has been recommended to obviate the necessity of obtaining an additional supply. In this town one factory uses 200 000 gallons of water per day, — amounting to 20 gallons per person per day, — the water being furnished under a fifty-year contract, the town to receive one-half cent per thousand gallons. There are other factories in the town which are supplied with unknown but probably smaller amounts of water. The town uses cement-lined, wrought-iron mains, which are laid in a sandy soil where leaks of considerable size would remain undetected for a long time. There is also a very large summer population, which increases the draft during the summer months. While the general introduction of meters in this town would undoubtedly result in a saving of water, and should be unhesitatingly recommended, it is certain that results like those obtained in the cities of Brockton, Fall River, and Providence are not possible, and it is doubtful if the consumption in this particular town can be reduced to less than from 80 to 90 gallons per person per day, without restricting the use of water in the factories.

I do not wish to be understood to question in the least the advantages of selling water by measurement. I am convinced that it is the only proper method of selling water, and that it should become universal. Neither do I question that a great saving in the use of water can be made by the introduction of meters. The most recent experience, however, shows conclusively that the extravagant claims which have been made as to the reduction in the quantity of water made possible by the introduction of meters are not fulfilled, and I have endeavored to show by an analysis of the figures some of the reasons why the predicted results have not been accomplished, and why they are not likely

to be accomplished with the present tendency toward a greater use of water for almost every purpose. I have also endeavored to show that a prediction as to what meters will accomplish in any particular case should not be made without some knowledge of the principal sources of use and waste, to determine how much of the consumption is susceptible of regulation by meters.

DISCUSSION.

President John C. Whitney. Gentlemen, the paper is now open for discussion. There is an opportunity for the gentlemen representing the communities referred to by Mr. Johnson to explain why it is that meters have not restricted the consumption of water in certain places.

Mr. George A. King.* Mr. President, there is one point which, it seems to me, bears on this question that Mr. Johnson has not touched upon, and that is the care of the meters. I noticed that in a great many of the cases quoted the consumption decreases for five or six years, and that it then begins to increase. With the little experience that I have had, I have noticed that after four or five years the meters do not do their duty, and they should be taken out, cleaned, and repaired, and that then they will register as they should. If an increased consumption is not followed by an increased bill, the consumption will further increase. The increased consumption may not be shown by the meter because it is more or less out of order. I think that this may account for some of the increases in consumption based on the pump records. I have one case in mind where I took out a meter on which there were four tenements. Those four tenements had not been consuming 40 000 gallons a year, according to the meter. For the first year, or a little over ten months, I think, after the meter was changed, the bill increased from $10 to $25, and last year the bill was over $30. I think that the lack of care of meters may account for some of the difference which Mr. Johnson shows.

The President. I wonder if Mr. Johnson has taken into account, in making up his figures, the date of the introduction of sewers into these various towns?

Mr. Johnson. I gathered together some figures to show the

* Superintendent of Water Works, Taunton, Mass.

effect of the introduction of sewers on the consumption of water, but the information was so meager that I did not care to present it. I found that the average consumption for the year previous to the introduction of sewers in six cities and towns was 42 gallons per person per day. In the same cities the year after the completion of the sewerage system the consumption was 48 gallons per person per day. The increase in the consumption in seven years previous to the construction of the system was 9 gallons per person per day, and in the six years after the completion of the system the increase was 13 gallons per person per day.

Mr. Charles W. Sherman.* There is one other point which Mr. Johnson has not touched on, and which might in the case of some of the smaller cities and towns have some effect on the figures of per capita use of water, where the figures presented are based on total population, and that is a gradual extension of the water system to include a larger portion of the town. In the case of small towns especially there are often outlying districts of considerable extent which are not reached by the water system, and if the total population of the town is taken in figuring the consumption, the result would naturally be materially different from the consumption per person actually supplied. As the works gradually extend to the outlying districts the per capita consumption would tend to a larger figure, even though the actual consumption or use of water per consumer remained unchanged. That consideration should be borne in mind in considering the smaller places; probably in the larger it would have no appreciable effect. Referring to the question of water unaccounted for, I am somewhat familiar with the records of a small water company in Iowa, where the policy of metering every service was adopted about three years ago. The main pipe system was constructed ten or eleven years ago, and it has not, of course, been possible to overhaul that. The best estimates possible of the amount of water used for street watering and for any other unmetered use of water, as at fires, — which represent comparatively small quantities, as the town is not a large one, — are made, and a reasonable allowance made for slip of the pumps; and upon that basis the quarterly records of the water pumped, as compared

* Civil Engineer, Boston, Mass.

with the quarterly meter readings, shows the amount unaccounted for to be about 33 per cent. of the total water pumped. The mains have been carefully examined so far as possible, and the whole system has been examined for leaks back of the meters. Some were discovered in the first examination, but not enough to make an appreciable effect on the percentage unaccounted for. In making the investigation, we found what perhaps many of the members may not be familiar with, — a little instrument known as the phonendoscope, once used by physicians, which is practically a type of stethoscope, in which the diaphragm has a little metallic or hard rubber rod extending from it. This can be put against a gate valve in listening for leaks, and the ear tubes, as in the ordinary stethoscope, concentrate the sounds very nicely. The whole instrument is contained in a little nickeled box about 3 inches in diameter and an inch and a half thick. It is a very valuable instrument for such purposes.

Mr. Walter H. Richards.* Mr. President, in this connection I should like to refer to an incident that has just come to my notice. A superintendent of water works in a small town referred to me to see if I could help him out of this difficulty: He had a new meter on some buildings which had been in use about a year, and he was not satisfied with the registration, so he put on a second meter, on the same line of pipe, and after taking the registration for a month or two, he found that it registered 39 per cent. less than the first meter. That did not satisfy him, so he put on another meter, and after running a month or two, that registered about 35 per cent. more than the second meter and 9 per cent. less than the first one. As he had no meter tester, he sent them on to me to test. I tested them and found them all practically correct, every meter, from my testing. There was considerable sediment, iron rust, came out of the meters when we blew them off, as we have to do before testing them.

Regarding the showing of the tables presented to-day, while they show an apparently increased consumption per capita with the introduction of meters, this increase is not necessarily waste, and as a matter of fact the waste may be, and probably is, reduced, the increase being due rather to the increased use of water-closets,

* Superintendent of Water Works, New London, Conn.

baths, or other sanitary fixtures made possible by an extension of the sewer system; and even the establishment of a large factory might increase the per capita consumption. That the per capita consumption increases and is increasing for local special reasons is undoubtedly true, and that the introduction of meters decreases the waste is equally true and proven.

The tables illustrate the fallacy of drawing conclusions from statistics when some of the factors are omitted.

Mr. John F. J. Mulhall.* Mr. President, there was one question overlooked in Mr. Johnson's paper; that is, in reference to slip of pumps. In Mr. Wheeler's companies, — he and his associates operate about twelve, — we keep daily records of the pumpage, and make an average per year of the annual consumption in Massachusetts. The average per capita per year seemed to us so enormous that we made an investigation and found that the pumps showed a slip of between 20 and 30 per cent.,— between 40 and 50 per cent. on one pump. I understand that Mr. Johnson has given figures computed on the displacement of the pumps, and that would account, in some cases, — in fact, I think in the great majority of cases, — for the great percentage of unaccounted for water, in addition to the leaks in the system.

Mr. Dexter Brackett.† Mr. Johnson's paper is a very valuable contribution to the literature on this most important subject, and I am pleased to note that he believes that the only proper method of selling water is by measurement. It must not be expected, however, that the measurement of water supplied to individual water takers will prevent leakage and waste from the street mains. What is required in order to obtain the best results is a complete system of measurement of all the water used, not only that used and wasted by the individual water takers, but also that wasted from street mains as well. If, with a system having 95 per cent. of the services metered, only 25 per cent. of the quantity supplied is accounted for by the meters, it can safely be assumed that there is a large leakage from the street mains, which should be prevented. By supplying sections of a distributing system through large meters, leaks from the distributing

* Water Works Accountant, Boston, Mass.

† Chief Engineer Metropolitan Water Works, Boston, Mass.

pipes can often be located, and the stopping of a few of these leaks often results in the saving of a large amount of water.

I think the writer has underestimated the quantity of water which is wasted from faucets intentionally left open, and I cannot agree with the opinion that all water which is intentionally drawn from water fixtures may be considered as legitimately used, including water allowed to run to prevent freezing of services. As an illustration of the quantity used for this purpose, the following examples taken from records of the Metropolitan works may be mentioned. The average per capita consumption in the city of Chelsea during the months of December, January, February, and March for the past three years has been respectively 55, 52, and 41 gallons greater than the average for the months of November and April. As the only cause for increased use during the winter months is the waste to prevent freezing of services, it follows that the average family of five persons in the city of Chelsea uses yearly about 30 000 gallons of water for this purpose, which, at the usual meter rate of 30 cents per 1 000 gallons, has a value of $9. The actual quantity used by those who follow this practice is much greater because not all the water takers find it necessary.

The city of Boston used about 30 gallons more per capita during the months of December, January, February, and March than during the months of November and April, indicating a use or waste of 10 gallons per inhabitant, or 6 000 000 gallons per day *for the whole year*, for preventing the freezing of services, — a quantity which can hardly be considered insignificant.

Doubtless a few water takers will use some water for this purpose even if supplied by meter, but in places where meters are in general use the increase in the quantity used during cold weather is comparatively small. In Belmont, Malden, Milton, and Watertown, where practically all the services are metered, the per capita consumption during the winter months of 1906 and 1907, as compared with that of the months of November, 1906, and April, 1907, was as follows:

	Average Nov. and April (Gallons).	Average Four Winter Months (Gallons).
Belmont	54.5	57
Malden	47.5	49
Milton	42.0	41
Watertown	66.0	60

It cannot be expected that the per capita consumption in cities which have a large transient population, or where there is a large use of water for business and manufacturing purposes, can be reduced by the use of meters to 50 gallons, and in some cases probably not below 150 or 200 gallons; but the experience of the cities and towns of New England where water is paid for in proportion to the quantity used proves that in places having a population of less than 50 000 the average per capita consumption should not exceed 50 gallons unless the manufacturing use is disproportionately large. On the other hand, in a city like Buffalo, N. Y., where the cost of water is small, and where the 2 per cent. of the water takers who are supplied through meters use a quantity equivalent to 46 gallons for each inhabitant of the city, the universal use of meters would probably not reduce the per capita consumption below 150 or 200 gallons.

During the past twenty years there has been a great increase in the number of water fixtures per capita, an increase in the quantity of water required per fixture, and a tendency toward an increase in the pressure furnished, all of which tend toward an increase in the use of water. So long as the water is paid for at schedule (fixture) rates the water taker has little interest in the quantity used, but with the general use of meters more attention will probably be given to the determination of the number and size of fixtures required to give the best results, as in the case of lighting at the present time, where attention is now given to the question of obtaining the burners which give the best results with the least expenditure of gas and electricity.

The quantity of water used in the eighteen municipalities supplied by the Metropolitan works is now measured by Venturi meters, and figures showing the per capita use of water in these municipalities may be of interest in the study of this subject. Table No. 12 gives the per capita consumption, as well as the population and percentage of services metered in the different cities and towns supplied by the Metropolitan works for the year 1906:

TABLE No. 12.

POPULATION, PERCENTAGE OF SERVICES METERED, AND CONSUMPTION OF WATER IN THE MUNICIPALITIES OF THE MASSACHUSETTS METROPOLITAN WATER DISTRICT. 1906.

City or Town.	Population. 1906.	Per Cent. of Services Metered.	PER CAPITA CONSUMPTION. (Gallons.) January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Av. for Year.
Boston	601 430	5	158	162	154	146	149	151	148	149	149	143	141	165	151
Somerville	70 950	19	88	88	83	81	90	93	92	94	92	89	84	92	89
Malden	39 040	78	51	50	49	50	52	54	55	53	54	48	48	49	51
Chelsea	38 000	10	102	117	106	92	89	92	93	97	97	87	83	113	97
Everett	30 270	2	83	91	84	78	80	83	80	82	80	74	69	87	81
Quincy	28 300	3	105	107	108	103	112	117	109	113	115	99	95	97	107
Medford	20 080	8	91	94	90	90	104	105	103	108	117	104	96	101	100
Melrose	14 650	3	112	111	109	111	113	106	108	110	113	107	101	106	109
Revere	13 390	4	67	74	73	66	80	97	99	104	93	73	68	85	82
Watertown	11 550	93	60	59	60	64	73	74	70	69	71	71	69	61	67
Arlington	9 940	22	70	75	72	72	88	90	83	87	94	82	76	76	81
Milton	7 120	100	36	35	39	42	62	64	56	61	61	47	43	44	49
Winthrop	7 240	2	98	104	98	96	106	127	135	145	131	107	98	110	113
Stoneham	6 350	2	62	63	59	62	67	69	69	76	84	78	72	71	69
Belmont	4 410	100	38	38	45	54	76	77	71	76	92	65	52	56	62
Lexington	4 230	2	57	60	62	74	97	101	96	98	92	79	68	66	79
Nahant	1 850	18	62	68	62	68	69	74	68	80	82	48	74	85	71
Swampscott	6 240	0	87	75	68	71	74	78	87	96	88	68	76	66	79
Metrop'lit'n Distr't,	915 040	12	132	136	129	123	128	130	127	129	129	122	119	138	128

Mr. Robert J. Thomas.* Mr. President, I noticed in Mr. Johnson's paper that Lowell was an exception to the rule, and doesn't quite coincide with his conclusion as to the increased consumption of water after meters were placed. According to his diagram and the figures for 1906 in my possession, the consumption of water in Lowell for 1906 was the lowest it has been for seventeen years.

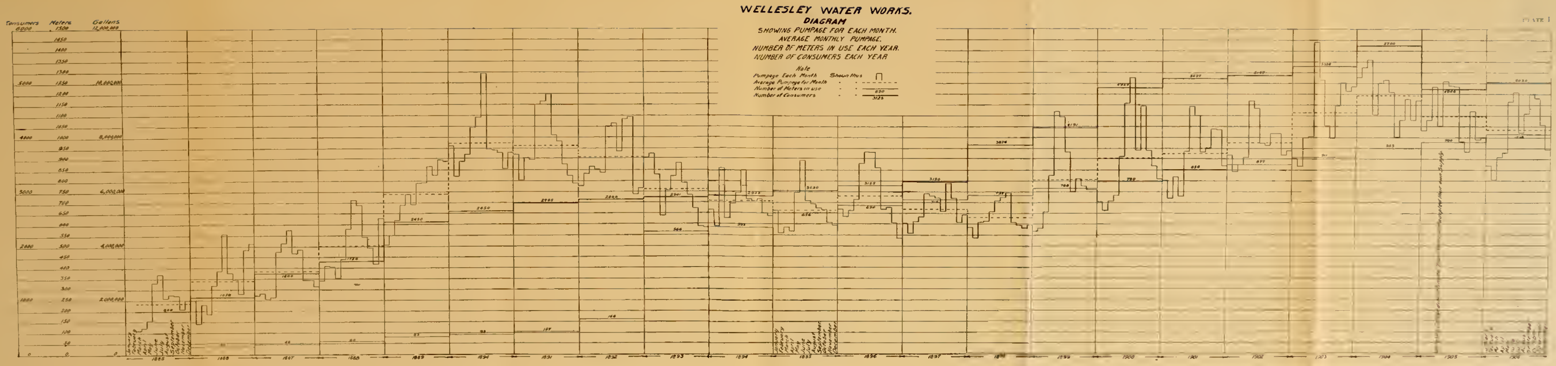
This decrease in consumption is due, unquestionably, to the use of meters. For a number of years the city of Lowell put on meters as the consumers of water applied for them, and those applying for meters generally were people who built good houses to live in themselves and were satisfied that they would save money by meters. In other words, the placing of meters was optional. Consequently that didn't affect the consumption of water greatly. But in 1900, several years after driven-well water was introduced, the water board applied meters to a thousand services where they believed, from the reports of their inspectors, that water was being wasted. The effect was almost immediate — within the year. A decrease of consumption took place, and ever since this compulsory placing of meters on all new services has carried that same result along with it. The reduction in the consumption of water began in 1900; and the consumption has been working down, so that last year, 1906, it was the lowest for seventeen years, due undoubtedly to the enforcement of the meter system and the placing of a thousand meters on the most wasteful services.

As to the matter of the improvement in the quality of the supply having anything to do with it, I doubt very much the effect of that, because, as I said, although the new water supply was introduced in 1896, — that is, the well systems were built then, — it was since then that this great decrease in the consumption took place.

Now, Mr. Johnson speaks of Yonkers and the great increase of the consumption of water there. I know for a fact that in Yonkers they improved the water supply recently. They put in driven wells and they filter their water, so that ought to decrease the consumption as it did in Lowell, instead of increasing it.

In regard to the assumption that letting water run in winter season to keep it from freezing is legitimate, I take issue with Mr. Johnson. I think a house where the water pipes will freeze is not a fit habitation for a human being.

* Superintendent of Water Works. Lowell, Mass.



WELLESLEY WATER WORKS.
DIAGRAM
SHOWING PUMPAGE FOR EACH MONTH.
AVERAGE MONTHLY PUMPAGE.
NUMBER OF METERS IN USE EACH YEAR.
NUMBER OF CONSUMERS EACH YEAR
Note
Pumpage Each Month Shown thus
Average Pumpage for Month
Number of Meters in use
Number of Consumers
Consumers
Meters
Gallons
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1899
1900
1901
1902
1903
1904
1905

The average daily consumption in Lowell last year was about 5 000 000 gallons, with a population of about 100 000 people. If we had not applied meters our consumption would be nearly three times as much, and if it were, we would have to use Merrimac River water to-day, because the quantity of well water would not be sufficient to supply such extravagant and excessive use of water. And that would mean a very serious proposition for the city of Lowell. In 1890 Lowell had over 496 cases of typhoid fever and 124 deaths when using Merrimac River water. Last year, using well water, there were 7 deaths from typhoid fever, with about 27 cases. That speaks for itself. That is an argument in favor of meters very convincing to me.

Mr. Frank L. Fuller.* Mr. President, I want to second what has been said in regard to the value of the paper which Mr. Johnson has presented to us. I know from experience in investigating such subjects that he must have put a large amount of work into it, and I think he deserves much credit for what he has done.

Just before coming to this meeting I received the proof of a diagram which has been prepared for the Wellesley water report for 1906 (Plate I). This diagram is instructive and throws light on the question of the introduction of meters.

The Wellesley works were built in 1884, and the use of water commenced the following year. Almost immediately the use of meters began in a small way. Their use was not compulsory, but water takers were allowed to install them, and a rate for metered water was established.

The amount of water pumped increased very rapidly. For instance, in 1886, with 1 058 consumers, the average pumpage was about 2 700 000 gallons per month, and this increased until, in the year 1890, with 2 650 consumers, the pumpage was a little less than eight million gallons per month.

At the close of the year 1892 there were 164 meters in use. The next year (1893) 402 meters were added, and at the close of that season 566 were in use. The number of service taps at the close of 1893 was 610, which indicates that meters had been placed on nearly all services.

The 402 meters mentioned above is the largest number of meters installed, or likely to be installed, in any one year.

* Civil Engineer, Boston, Mass., and member of Water Board, Wellesley, Mass.

As soon as nearly all consumers used water through meters, the pumpage of water began to decrease. By an examination of the diagram it will be seen that the amount of water pumped in 1890 was about the same as in 1902, or twelve years later, while the number of consumers had increased from 2 650 to 5 147, or had nearly doubled.

I do not know what the condition of the Wellesley water supply would have been at the present time if meters had not been introduced. Before meters began to be generally used, the pumpage practically doubled every second year. The town would have been compelled to go outside of its own limits to secure a new supply, or would have been driven to the expensive expedient of installing a plant for the filtration of the water of Rosemary Brook or Charles River. With all consumers metered, the town of Wellesley now has a sufficient supply for some years to come.

The following table is obtained by dividing the total pumpage for each year (obtained from the plunger displacement) by the number of consumers for that year. It, of course, includes water used for sprinkling streets and lawns and the small amount used in extinguishing fires and flushing pipes. It is somewhat too large on account of insufficient allowance for slip of the pump, which was corrected for the year 1906. The pumping engine is of the duplex pattern, made by the Geo. F. Blake Manufacturing Company in 1884, and has a capacity of 1 000 000 gallons in twenty-four hours.

Year.	Daily Supply of Water per Consumer. Gallons.	Year.	Daily Supply of Water per Consumer. Gallons.
1885	64	1896	62
1886	84	1897	55
1887	67	1898	43
1888	77	1899	51
1889	79	1900	48
1890	97	1901	48
1891	91	1902	50
1892	84	1903	55
1893	69	1904	55
1894	63	1905	59
1895	58	1906	54

I should like to emphasize what has been said in regard to the importance of knowing the exact amount of slip to be allowed

for when pump records are used in determining the amount of water pumped during the year. The Wellesley pump was tested last year and the slip found to be about 11 per cent. An allowance had previously been made, but probably not enough. All pumping engines should be tested for capacity as often as practicable,—at least once in two years,—if fairly accurate results are to be expected. It is probable that most pumps are not delivering the amount of water with which they are credited. In towns where the entire consumption is metered, a portion (it may be small) of the great discrepancy between the pump and meter records may be due to overrating the capacity of the pump.

Dividing the total amount of water passed through meters in Wellesley by the number of consumers, we have as the average daily amount of water *used* by each consumer, 33 gallons. The difference between this amount and the 54 gallons obtained from the pump record is 21 gallons per consumer, which is lost in various ways.

In order to locate this loss, our superintendent made a careful test of our 600 000-gallon covered reservoir (the one ordinarily used) for twenty-three hours and found it practically tight. We have in use one of Mr. Winslow's recording gages, and from the card which comes from the dial it appears that there is lost from the system during the twenty-four hours about 16 gallons per consumer. This is based on the loss from 12 o'clock midnight to 5 o'clock A.M. By taking this draft, when there should be little or no consumption, deducting the flow of three drinking fountains, and applying it to the entire twenty-four hours, an amount of 16 gallons, as mentioned above, is obtained.

Probably a very small part of this amount is legitimate use, but most of it is no doubt due to leakage from the pipe system, which is composed of 32.7 miles of cast-iron distribution pipe and 20 miles of wrought-iron cement-lined service pipe, a total of nearly 53 miles. In many houses there is more or less dripping from faucets due to defective washers or to the fact that they are not closed tightly. A little silt or a particle of solid material may lodge under a valve in a water-closet tank and allow the escape of a small amount of water. These leakages may often be too small to move the piston or disk of the meter, and thus be unrecorded.

As a matter of interest and information, I keep a record of the daily reading of the meter in my own house. During the last thirteen years the average daily consumption per person per year has varied from 12 to 24 gallons. This amount has been largely used within the house, but little being used for watering lawn or garden. The house for twelve of the years mentioned contained water-closet and bath-tub. Set tubs for washing were added last year and will, no doubt, act as a factor in increasing the amount of water used. There is no sewer system in Wellesley.

The facility with which water can be obtained and disposed of in a house has much to do with the amount used.

As previously mentioned, the average metered consumption in the town was 33 gallons per consumer. In my own family it has averaged for thirteen years 18 gallons per day per consumer. So far as indoor consumption has been concerned, only moderate care in the use of water has been exercised.

The use of meters in Wellesley has been entirely satisfactory and their use has saved the town many times their cost, in putting off the time when great expense will be required for a new or increased supply.

Our meters have been carefully attended to, and the cost last year for maintaining a little over 1 000 meters was $270, or less than 27 cents each.

There is probably no doubt, as Mr. Johnson has pointed out, that even with meters, owing to greater facilities in using and disposing of it, the consumption of water is increasing from year to year, but there is no question in my own mind that without meters the increase would be vastly greater. The results at Wellesley confirm this opinion.

Mr. George Cassell.* Mr. President, as Mr. Brackett has stated, Chelsea is one of the most wasteful cities in regard to water in the Metropolitan district, and in view of the fact that Mr. Johnson has made a statement to the effect that water meters do not accomplish the stoppage of waste (if this is true, I find myself in the position of advocating something that doesn't amount to anything), he has completely knocked my statements into a cocked hat.

* Superintendent of Water Works, Chelsea, Mass.

Now, I want to say a few words in relation to Chelsea and its consumption of water. Our city is supplied by gravity, is in the Metropolitan water district, and we are very cosmopolitan. We have a very condensed population, and a population of a character which should, perhaps, use more water than any other city; but we cannot all be Brookliners or Newtonians. [Laughter.]

Aside from the statement that the use of meters for stopping the waste does not accomplish the purpose, I believe that it is the only legitimate way in which to sell water to people who want to use it; especially in those cities that are in the Metropolitan district and where the water is purchased by measure. The old method of assessing by the fixtures, or otherwise, is antiquated and gone by. There is no justice in it; it is all guess work.

We started into the meter business because of the fact that we were attached, as I said before, to the Metropolitan water district, and the officials are not very slow in charging one for what he gets; and instead of coming down in price they keep going up. I don't know as I blame them any, because if the people are bound to waste the water they must pay the bill, and the only way to make them do so is by installing a meter and have them pay for what they use and waste.

In 1905 we had installed 951 meters. Previous to that our consumption was, I believe, 110 gallons per capita. In November of that same year we dropped to 82 gallons per capita, and of course I laid it to the use of meters, but I see that I was wrong. [Laughter.]

In December last we had a little cold snap and were informed by the state that the consumption had increased from two million and a half up to four million and a half per day, and that caused me to do a little thinking. I could only figure it out in one way, — that the increased consumption was due to the fact that the people were letting the water run to keep it from freezing. Now, I don't know in what sense Mr. Johnson used the word "legitimate" in connection with his view of it, but it didn't appeal to me, as the majority of those letting the water run were not occupying metered premises, and I have the practical side of it. Aside from that, however, in this steady cold snap that we have just had, the consumption increased until it got up to approximately

173 gallons per capita, or an increase from 3 000 000 gallons to 6 550 000 gallons daily, and that, according to Mr. Brackett's statement, was costing the people in my city approximately $150 a day.

Now the injustice of it comes right here. That was practically water which was wasted in consequence of the cold condition of the houses, the occupants of which let the water run to keep the pipes from freezing. As Mr. Thomas said, the houses were in such a condition that they had to let the water run to keep it from freezing. If that is legitimate use, and the people want to pay for it, all right, if the premises are metered and the state can supply the water.

Under the flat rate, the man who is not obliged to let the water run because his house is warm is the sufferer, as he is made to pay for what the other man wastes; but still they tell you it is an injustice to put a meter on his house to curtail that " legitimate," use of water by letting it run to keep it from freezing.

As I said before, we jumped from 82 gallons per capita in November to 173 gallons per capita during the cold period, which meant practically 91 gallons per capita waste; and if we could get along with 82 gallons per capita, including manufacturing and everything else, in November, why couldn't we do it every month? The question answers itself. It was simply because of the cold snap and the water being allowed to run until such times as tenants became satisfied that the weather was such that the water wouldn't freeze any more.

As previously stated, we have installed 951 meters. We collected with these during the year an excess of close to $10 000 over and above the minimum charge, which was $12 for the year. That was all very well in one sense, but it was hard on the water registrar in another, and as I happen to be the registrar in my city, I got the practical side of it everywhere. The fact remains, however, that if we are going to stop the waste of water we must educate the people up to the use of the meter, no matter what the result is, and I thoroughly believe that meters are the only legitimate means to stop the waste. You may talk about inspectors all you please. Why, there would have to be one stationed at every house!

One day I met a gentleman of Jewish extraction, a very nice man, and he said, " My God, Cassell, I paid $300 last quarter for water; what do you think of that?" " It is too bad," I replied; " how did it happen? " and he said, " The people in the houses let the water run to keep it from freezing." I said: " Those are nice houses that you have built down there and the plumbing looked all right; did you do anything to prevent the pipes from freezing? " He answered, "No." " Why didn't you pack the pipes? " I asked, and he replied, " What is the use? They will tear the boxing away and burn it up and everything that is around it." [Laughter.] I said to him, " Who is to blame? " " Oh," he answered, " the damned people who live in the houses. They are so damned ignorant you can't do anything with them. I put door strips on the doors to keep the cold out of the houses, and what do you think? They stole them all off." [Laughter.]

Now, that is exactly so. It is a hardship, we must all admit, upon the owners of houses who, no matter how patiently and conscientiously they try, cannot control the people who occupy them.

In our city we have a large but not very wealthy population, and a good many times I am surprised, when I get into an argument with gentlemen of my city, because they try to compare it with Brookline. [Laughter and applause.]

Now, gentlemen, mark me, I am not disparaging my city. There is no man more loyal to his city and the people in it than I am. I believe I am living in the queen city of the state. But it is not the city, it is the people. [Laughter.] Therefore I say that it is a hardship for us in this city, under its conditions, to try and establish a meter system. I heartily believe in what has been stated here before in relation to a watch or any piece of machinery,—I don't care what it is,—you cannot set it going and let it run without repairing or cleaning it once in a while, and expect to get good results from it. It is so with a meter; it ought to be taken out and cleaned and looked after, and then the result of that meter will be right.

It is not a superintendent's or a water registrar's business how the people use water, but it is his business to see that all get justice, and I don't believe there is any superintendent but is laboring to see that the citizens get justice, though in no

greater measure than the city receives it; that is, equal to all. And so I say that if we are going to reduce the consumption of water in our cities, we must stand the burden of everything that goes with it until we accomplish that result, and the only way we can accomplish it is by being firm and impressing upon the people that we are trying to do what is right by them, and educating them up to that fact, and until we have done that, and not until then, will we accomplish what we are all trying to do, namely, bring down the consumption of water in our cities to a point where it is reasonable.

When you look at it, in the city of Chelsea 82 gallons per capita in November and 173 gallons in these last two months (or since we had have this cold snap), 91 gallons waste per capita going through the sewers, costing $150 a day, for what? To allow men who own houses, — who won't exert themselves to put the plumbing in so as to protect the pipes from frost, — to allow them to accomplish their object at the expense of others who do not have to waste the water in this manner. The work of protecting pipes from freezing can be accomplished in one house just as well as it can be in another if it were not for the fact, as my friend before mentioned said, "You cannot educate them up to it."

Mr. Johnson. Mr. President, I should like to ask the gentleman who has spoken what the population of Chelsea is?

Mr. Cassell. Thirty-eight thousand.

Mr. Johnson. And $150 to keep pipes from freezing amounts to about how much per person?

Mr. Cassell. Well, I —

Mr. Johnson. Less than one third of a cent a day for each person to prevent the plumbing from freezing in the houses.

Mr. Cassell. Yes, but, Mr. Johnson, there are other things to be taken into consideration besides that, which, if I had the time I might state, but I don't think I will take up the time because there is a gentleman waiting to be heard on another matter.

The President. Keep right on, Mr. Cassell.

Mr. Cassell. Before the Metropolitan Water Works sprung into existence we obtained our water supply from the city of

Boston, and at that time there were periods in the summer and winter when, in order to get a supply of water to take care of the population (and it was a great deal smaller then than it is now), we had to install a pumping-engine and pump from the low-service into a high-service reservoir, and we had to do that in the hours of the night when the population was asleep, and if it had not been for the fact that the Metropolitan water works of the state of Massachusetts had been created, God knows what we would have done for water, — and we don't like it any better than the rest of you at that. [Laughter.]

Now, Mr. Brackett will corroborate what I say, that notwithstanding the fact that the state of Massachusetts has spent $40 000 000 to create a supply of water sufficient for all the cities and towns within a radius of ten miles of the State House, and, according to their best judgment, have put in aqueducts big enough to bring it down, I am informed that if this same waste took place everywhere it would be impossible for them to supply the amount without going further and spending more millions of dollars. So, Mr. Johnson, it is not the one third of a cent, but there are other things connected with it which must be taken into consideration.

Gentlemen, I thank you very kindly and I will close.

Mr. F. H. Hayes.* Mr. President, I have in mind the investigation which has been going on in a town for the last ten days in the matter of displacement of water with our pump. All the water going through the pump is going through a large meter. It is an electrically driven pump, with recording instruments from the General Electric Company, and the displacement of the pump indicates so much more water passing than does the meter that we are going to weir the water to see which is right, whether it is the pump or the meter.

The President. I should like to ask Mr. Hayes what his idea is of average pump slippage.

Mr. Hayes. Three to five per cent.

The President. That is, a new pump?

Mr. Hayes. Yes.

The President. How about an old one?

* Of the Platt Iron Works Company, Boston, Mass.

Mr. Hayes. It depends on how gritty your water is.

The President. How high slips have you known?

Mr. Hayes. Oh, up to 50 per cent. You take a plunger pump traveling through a bushing without fiber packing and the slip is more than with the fiber packing. The pump we have in mind is a fiber-packed pump; it is a triplex pump; so we know pretty well that we are displacing the water; but we became so suspicious of the meter that was measuring the water, we have decided to submit it to weir measurement so we may know whether it is the pump or the meter, or where it is.

The President. Or the weir?

Mr. Hayes. Well, that will be up to the engineers.

Mr. Henry V. Macksey.* Judging from the arguments offered so far, it would seem that the general impression is that the author desires to prove that the use of meters will not prevent waste of water. I do not so understand the drift of his argument. Although he led us along with facts and figures to show that the first decrease in per capita consumption was not long maintained, he also said that in his opinion the use of meters was necessary and that their installation and use would surely continue. It would therefore appear that he does not differ materially from the many members of this Association who have studied this problem in all its phases for many years.

There is no doubt that many of the reasons offered to-day why meters do not continue to show the marked results secured on first installation are true. That the average meter is accurate and in good working order when first applied is undoubtedly a fact, but it cannot be expected to remain so forever. Water-works superintendents are usually compelled to produce great results on small incomes, and there is always a violent criticism of the cost of meter repairs by those who waste water and consequently despise meters. As the superintendent is usually very busy attending to his principal duty of supplying water at all times to all takers, and is hampered by lack of funds and of skilled labor, he often leaves the meters alone until they cease to register or break down, or prevent the flow of water on account of being stopped by rust or other foreign material. Then, out comes the

* Consulting Engineer, Boston, Mass.

meter. Suppose that the meter had been given as good care as an ordinary machine used in a shop gets; that it had been viewed once a year, or even once in three years, and was tested for accuracy and adjusted if necessary. Trouble and expense would have been avoided and a greater revenue would have accrued to the water department. It should be borne in mind that when a meter fails to do satisfactory work it is not useless. If the mainspring of a watch breaks or it stops on account of dirt, we do not throw it away. A dollar will pay for cleaning, or a new mainspring may be procured for from twenty-five cents to a dollar, depending on who does the work.

To say that the waste necessary to prevent freezing costs but one third of a cent per day per capita may be true, but that is not the proper way to look at the freezing problem. You should not figure on the bill for damage due to frost, in the general case, but on the interest on investment to permanently prevent freezing by proper construction. Mr. Thomas is certainly correct when he says that a dwelling wherein water freezes is usually unfit for human habitation. If we can force owners to so protect the plumbing in the dwellings of the poor that the water will not freeze, we will deserve credit for accomplishing a good work outside of our ordinary field.

That the per capita rate increases again after meters are applied should not discourage water departments. Remember that on a meter basis each taker is being charged for what he takes and no more, and that he can economize or be lavish in the use of water as he sees fit; and above all, let us not forget that the meter is not an instrument designed to discourage the use of water, but to stop waste or penalize the man who is responsible for that waste.

Mr. Brackett. Mr. President, I should like to ask Mr. Johnson how, if meters do not prevent the use of water to prevent the freezing of the service, does he account for the fact that cities and towns which are universally metered show very little increase in consumption during the winter season, while those which are not metered have, during cold weather, an increase of from 50 to 100 per cent.?

Mr. Johnson. Mr. President, perhaps my statement was a

little rash. What I meant by this statement was that a man who has a meter in his cellar would not be prevented from allowing the water to run if he thinks the freezing of his pipes would be prevented by that means. It may be that the introduction of meters will cause better plumbing to be put in; I have little doubt about it, not only in regard to freezing, but in other ways. I simply mean that on a particularly cold night, if I think that my water pipes are going to freeze, I will allow the water to run, meter or no meter, knowing that the increase in the water bill will be very small.

Mr. J. C. Gilbert.* I have been very much interested in the address, and also in the discussion, but there is one thing which I think we have neglected to look into, and that is this: Supposing none of us had meters, or suppose, for instance, there were no meters; what would have been the increase in the use of water? Of course the people, if they do not have them, are careless with their water; and although you may catch a man once in a while and tell him that he must be more careful, he doesn't care much about that; but if you finally decide to put on meters, then they will see that you are after them and for a time they will be careful.

We have seen by the tables here that after putting on meters the consumption of water has decreased very quickly. One reason for that is because the people see what is coming, and they know that if they use water they have got to pay for it, and for that reason they are more careful.

All the houses that are built at the present day have more fixtures, more plumbing, and, of course, they require the use of more water. But if we hadn't put on meters, you would find that these water-works systems which are paying good dividends would have been in bankruptcy long before this time. I tell you that people would use water to-day at a fearful rate if no meters had been put on. I think we should have been obliged to do something radical to stop the waste. And now, after metering these systems, we find the more fixtures we have in a house the more water they will use, and that, of course, increases from day to day, until it gets up to nearly where it was before meters were put on, but we have nothing to show how much more the increase would have been had no meters been put on.

* Treasurer of Water Board, Whitman, Mass.

I believe in meters; I think that it is the only way to sell water unless you have all the water you want.

In my town last year we used 46 000 000 or 47 000 000 gallons of water, and we put in 85 new services, and we have metered nearly every one of them, and this year, when we came to figure up, we have only used about 42 000 000 gallons. Do you think if we had not metered those services there would have been a decrease in the consumption of water? I do not. I think there would have been a large increase. I believe that meters are a necessity, and I do not believe that the water systems to-day could be run with any kind of profit if it were not for meters. I think it is a blessing to the whole country that they are in use to-day.

MAYOR BLODGETT.* Mr. President, when you called upon me before I had nothing to say, but I have something to say now. I want to say, in the first place, that Mr. Johnson is the only man who has talked to my liking about water.

I want to answer just one question about going into bankruptcy if meters were not used. We have in Woburn not one metered service, but we have a water plant there that is absolutely free from debt. How many cities and towns are there here that can say that? Not one. Our water plant has yielded a revenue of $25 000 a year, and there is now a surplus.

MR. CASSELL. Mr. President, notwithstanding the statements I have made, and the statements that the gentleman made about bankruptcy, and the fact that we use a great deal of water, — notwithstanding all that, we had a surplus of $39 000.

MAYOR BLODGETT. What did you do with the $39 000?

MR. CASSELL. Well, they threw it into what they call the contingent account. It is something like a hole in the ground. [Laughter.] It is like one of those wells to which there is no bottom, and if you can go over there and find out where it went to, I wish you would.

Now, gentlemen, I want to say that I am very grateful to Mr. Johnson for his paper and his talk, and I think I voice the sentiment of every member of this Association. If it hasn't done anything else, it has brought up a discussion, which I think has been very enjoyable and has met with some favor.

* Woburn, Mass.

Mr. X. H. Goodnough.* Mr. President, the charters originally granted to cities and towns authorizing them to supply themselves with water, did not contemplate the collection of a profit from the water works. It was assumed that only a sufficient amount would be collected from water rates to pay interest and sinking-fund requirements and the cost of management and operation of the works. The use of the water-works income for other purposes has, in fact, been specifically prohibited in some of the more recent water supply acts. If the latter practice shall become general, the cost of water to the consumer will eventually become very much smaller than it is to-day.

Under these conditions, in New England cities and towns, where the water works are, as a rule, well managed and the consumption of water is not unreasonably large, it can hardly be expected that in the long run any very material reduction in the use of water will follow the general introduction of meters.

Experience with water supplies in Massachusetts shows that there are comparatively few places in which records of the consumption of water are kept where the quantity consumed per person is unreasonably large; while, on the other hand, occasional measurements or calculations have shown that the quantity used in places where no continuous record of the consumption is kept is in very many cases excessive. In some such places the installation of a system for the continued measurement of the total quantity of water supplied to the city or town has been followed by a very material reduction in the use and waste of water without the general use of meters; and there can be no question that an actual knowledge of the quantity of water used leads to the prevention of illegal or unnecessary use and waste by the exercise of greater care and vigilance by the water-works authorities.

There can be no doubt that the general use of meters is a further check upon the excessive waste of water and tends to keep its use within reasonable limits, and the meter system is the simplest and most equitable method of distributing the water tax. It cannot be expected, however, that in places where the consumption of water is not excessive, the introduction of meters will reduce materially the consumption of water, or in places where the con-

* Chief Engineer, State Board of Health, Boston, Mass.

sumption is low, keep it from increasing, when the rates charged for water are diminishing.

Mr. Thomas. Mr. President, of course the reason why Woburn has no indebtedness and has a surplus every year is simply due to the fact that they charge more than they ought to. If every city and every water company in the state of Massachusetts charged more than they ought to, they would have a surplus and no indebtedness. It is all a matter of charging.

Mr. Fuller. Mr. President, it occurs to me that there is a great deal more water used to prevent freezing than there is needed for that purpose, and if just enough could be used to prevent that freezing, it would be a very small amount. I have occasionally let the water run to prevent freezing, though not very often, and I was surprised to find how little water it required. I think if the information could be spread abroad among people who allow the running of water to prevent freezing that it requires but very little, it would have a tendency to cut down this waste immensely.

The President. I am afraid, Mr. Fuller, that the only educator is the meter.

Mr. W. H. Richards (*by letter*). The tables presented by Mr. Johnson show, in a marked degree, the impossibility of comparing the consumption of one city with another without knowing all the factors which enter into the problem of per capita consumption. In a city where large quantities of water are used for mechanical or manufacturing purposes the operatives in the factories, who are a part of the population, are apportioned their share of domestic consumption and a portion of the water used for manufacturing purposes, thus raising the per capita consumption. On the other hand, in a city where a large proportion of the inhabitants consist of factory operatives living in houses without sanitary fixtures, where in fact, in many cases, the entire supply for several families is drawn from one faucet, the per capita consumption for domestic purposes is very low. This latter condition obtains in Fall River, and the per capita consumption there is further reduced by the non-use of water for manufacturing. Another factor in the problem is the sudden extension of the sewer system in a city, which often takes place several years after the introduction of water.

There is no doubt that in most of the cities mentioned in the tables there has been a sudden increase in the number of so-called sanitary fixtures in recent years, which tends to largely increase the per capita consumption, and a line in the diagrams showing this increase would probably account for much of the increase in per capita consumption after the introduction of meters. It is usual in most cities to meter all of a certain class of consumers at one time, and when the class where the greatest waste occurs is metered there is a sudden drop in the consumption, as shown on nearly all the diagrams, this showing the beneficial effects of meters in checking waste.

Does any man doubt that if all the meters were removed there would be a sudden increase in waste and a consequent increase in per capita consumption?

With the constantly increasing number of purposes for which water is used, it is probable that the quantity used per capita will increase for many years, but meters alone will keep down the waste and unnecessary uses.

There is one phase of the meter question which is often overlooked, viz., the equity of paying for water in proportion to the quantity used. There is no commodity, except water, which is sold at one price regardless of the quantity used. The injustice would be apparent if two bushels of potatoes were sold to one man for the same money as one bushel were sold to another man. Yet in the case of water at schedule rates the careful man pays not only his proportion of the expense of furnishing water, but also for the cost of furnishing his neighbor with water to waste; whereas under meter rates each pays for the benefit he receives and further pays for his neglect of consideration for his neighbor.

There are many questions in regard to meters which remain to be discussed as to the cost of accuracy, repairs, life, etc., but the fact of their efficacy in reducing waste is established beyond question.

Mr. Clemens Herschel * (*by letter*). The error lurking within the paper is one, it seems to me, of a misinterpretation and a wrong use made of statistics. I have always thought that hydraulics was a subject more capable of causing one to deceive

* Consulting Engineer, New York, N. Y.

himself than almost any other, unless it be the recognizing of the true meaning of, or the lessons to be drawn from, statistics; and when it becomes a question of properly using a combination of the two, the opportunities for self-deception become very great.

An inkling of one such error and of a class of such errors was given by President John C. Whitney when he referred to the construction of sewers while the statistics were being taken, and to the consequent change in the water-consuming habits of the people which developed during the statistic time. Mr. Sherman gave another argument against the acceptance of statistics taken in a formative community, — on the wing, as it were, — when he called attention to the fact that following the inauguration of a public water supply in a municipality comes a period in which the citizens learn to use water and put in fixtures to draw water. Naturally no correct use can be made of statistics taken during the course of such an era of water-works extensions without the houses of the people and within them. From data of this sort all those not strictly analogous and sound in every way must first be carefully culled out before they can properly be used in the diagrams made for the determination of facts or laws.

To illustrate: Take Table No. 1, on page 113. What does the paper care for the different characteristics or modes of government of the different cities cited? Some I happen to know something of. There is Bayonne, N. J., the home of the very large works of the Standard Oil Company; which alone, besides the Orford Copper Company and other minor manufacturing concerns, consume millions of gallons of water daily. I doubt if the consumption of water in Bayonne by consumers such as are found in the *average* city of that size is to-day so much as 40 gallons per person, and some years ago it was about 30. Under these circumstances what right has any one to call 100 one coördinate of a pair of rectangular coördinates, and write 95 in the other column for Bayonne, as is done in the table? How many more such defective figures are there in the table? And in the diagrams based on it, and in similar tables?

We are told that Brockton, Fall River, and Providence may likely be found, before long, less of an example to the others than they have been. Will that be on account of a proper increase in

the use, not waste, of water? Or will it be because by change of administration, or similar causes, vigilance and skill in the finding and remedying of leakage and waste of all sorts has relaxed, perhaps joined the majority?

We hope not. For we have largely profited by, and need, more than ever, their bright example.

Is it not all wrong to lay weight on and use, as the basis of diagrams from which to deduce laws, a set of statistics that deal with the effect of metering 25 per cent. of the taps of any one city? What does that teach us of the *character* of the draft from either the 25 per cent. or from the remaining 75 per cent. of the taps?

When left to the consumers it is the wise and thrifty who put in meters, while the shiftless and wasteful fight against them, and prefer to let the others pay for the water they themselves waste.

It will not do to infer merely from statistics taken with a free, liberal hand, and then plotted on an assumed system of rectangular or other coördinates. Instead of this, a lot of thinking about the true and precise meaning of each item, and of culling out, must be kept up to permit of valid deductions being drawn from the finally remaining lot.

It is said that Lord Palmerston, prime minister of England, once called in his chief statistician, wishing to be informed as to pending legislation on, we will say, the culture of rice, and asked him to go and prepare for use the established statistics concerning rice. Much to Lord Palmerston's surprise the man hesitated and hung back, and being asked why he did not go and do as he had been told, blurted out, " But, my lord, what is it you wish to prove? " He had facts enough on file, but according as his statistics were handled and marshaled, they could be made to support one feature of an argument or another.

Can we not do better than limp along in this matter with leaden feet, in the distant wake of uncertain and obsolescent statistics?

Nobody wants to reduce or restrict legitimate use, or cares particularly just where laudable habits of the people will bring it. What we are after — our ideal aim — is the utter annihilation of *waste;* and the complete way to accomplish this is to start fair, or to bring waste to a reasonable figure, and then to maintain that condition; and the way to do this is to make a daily, if

possible, — at all events a short term, — continuous routine comparison between income and outgo. In a paper I expect soon to publish I have said as follows:

The case of the East Jersey's Water Company's fifty miles of pipe line has already been given as an example of water waste prevention by a controlling and checking of leakage as it arises. On that method of work hang all the law and the prophets relating to water-waste prevention in any kind of a hydraulic plant. In the last analysis the prevention of water waste depends on naught but a daily measurement of income and outgo, and the keeping of these two in constant agreement. If a meter be placed at each end of a pipe line 23 miles long, as was done when the conduits of the East Jersey Water Company were built, it is very evident that the daily records of these two meters must agree, or else there is something wrong about either the meters or the pipe line; and if the meters are in order, leaks must be sought for and remedied on the pipe line between them.

In a larger sense the above-described procedure is all that is necessary to control and check waste and leakage on any kind of a pipe-line or system of pipe-lines up to the complex, but to treatment perfectly amenable, case of water supplied to a city district and consumed within it by resident families, shops, and manufactories.

This opens up a large subject, but ill undersood, especially so in the United States, where a street-main leakage of 20 gallons per inhabitant and more is considered an infliction of Providence or due to the climate, or to the peculiar habits of free-born Americans, or to most anything else than to the municipal shiftlessness not infrequently encountered in the United States, or to lack of the proper amount of work expended to control street-main leakage by the water-works administration; which alone has allowed it to grow to the existing serious dimensions through the course of perhaps fifty years of frequent changes of administration.

Nor will spasmodic examinations and reports made upon them change the situation. This is only the old story of house-to-house inspection of plumbing fixtures to prevent waste on the consumers' premises over again, and as applied to the case of cities wasting out of the street-mains. So soon as the inspector's back is turned, waste renews its insidious work and is once more on the increase.

There is only one way to keep control of street main leakage, and that is by a continued system of frequent, or so long as it is necessary, of *daily* measurements; best by means of twenty-four hour chart records, which will serve to note the course of or *the*

beginnings of sources of waste, and by thus first placing and then keeping waste under subjection.

The city should be divided into districts, any one of which could be shut off from the rest and have its supply graphically and continuously measured and recorded at any time, day or night, and as long as desired. Then by well-known means, all consumers should be metered; and once the accuracy of these meters is known, leaks and waste outside of the consumers, premises can likewise be sought for and remedied.

In an examination of this sort once made by Mr. Winslow H. Herschel, civil engineer, a son of the author, the final result was that it would be profitable for the city to meter every tap and also to check waste out of street mains, as thereby that city could be made to supply its then inhabitants, and its future growth of inhabitants as well, for *fifty years*, from the quantity then consumed (used and wasted) within its city limits.

As the situation in the United States in the respects referred to may not be known to the reader, it is proper here to say that one city frequently commits the folly of pumping over 400 gallons per inhabitant per day into the sieve that represents its distribution system, the wide-open plumbing fixtures of its inhabitants included; and 350 gallons per inhabitant is an ordinary quantity to be consumed in that city.

A school of water-works philosophers and bodies of complacent officials have grown up who will argue that 150 gallons per inhabitant is too small a quantity to provide for a city, when half that quantity could readily be reached or approximated; and that city water main waste cannot be reduced to the terms that obtain in Europe; or in the distribution of gas in cities at home (frequently as low as 12 per cent. of the output). Yet all this time the city of Providence, R. I., in the United States, a city of some 200 000 inhabitants, the center of a large suburban district, housing many thousands of transient visitors daily in addition, and a large manufacturing center as well, has never consumed much over 60 gallons per inhabitant per day, and has brought this about by mere ordinary methods of good housekeeping; while smaller places in the United States have approached or reached 30 gallons per inhabitant.

There is room for much good work to be done, so much is evident, and though hitherto the laborers have been few, signs are not wanting and are indeed active that a permanent work of municipal water waste prevention will take up much of the attention of American engineers in the future.

Mr. Paul Hansen * (*by letter*). This is an exceedingly val-

* Assistant Engineer, State Board of Health, Columbus, Ohio.

uable paper and is the first in which such extensive data have been brought together to show the effect on consumption of metering a public water supply. It is instructive in showing both the advantages and limitations attending the use of meters. With the advantages we are more or less familiar, but the limitations are brought out only by a careful study of facts and are not very apparent from theoretical considerations. Further, the paper brings out, in a striking manner, the value of a pure water supply in reducing waste consumption, an economic advantage that needs to be brought forcibly to the attention of many water-works officials.

Following out the logical lesson of Mr. Johnson's studies, it should be recognized that the apparent failure of meters to reduce water waste is not due to the inability of meters to accomplish this result, but to the fact that nearly all of the supplies considered are imperfectly metered. If on a given water supply *all* services were metered and a good meter also placed on the discharge main from the pumps (or conduit main in case of a gravity supply), the detection of any serious waste would be a comparatively simple matter. This applies equally well to waste of energy through slip of the pumps. The few measurements of slip on water supply pumps in the state of Ohio would indicate 25 per cent. to be the rule, and in one case, and that a pumping engine of no mean size, the slip was 40 per cent.

Furthermore, the universal use of meters involves the keeping of more complete records, which in itself is a great gain, for great sums of money are lost by inefficient operation, which inefficiencies are never discovered for lack of figures to bring them out. While no exact figures are available, an examination by the writer of a large number of water supplies in the state of Ohio has convinced him that many thousand dollars could be saved if only the difference between the actual amount of water pumped and the calculated amount as registered by the pump revolution counters could be ascertained. At least as much more could be saved if the difference between the actual amount pumped and the amount paid for by consumers could be ascertained. If by the universal metering of a supply the waste could be kept down to a reasonable amount, the increase in consumption in all but

a very few exceptional cases would be entirely unobjectionable, for the water used would be paid for and any increase in consumption would then fully justify a corresponding extension of the supply to meet such consumption. Thus, to the writer's mind, the point most forcibly shown in Mr. Johnson's excellent paper is the necessity for the complete metering of supplies in order that the best results may be obtained.

Mr. E. M. Peck * (*by letter*). I feel it not only a duty but a privilege to commend Mr. Johnson's paper; and while most of the statements he advances have become fairly well known to active water-works men, I doubt if ever before they have been so comprehensively and convincingly presented as in this paper.

The statement that because meters have accomplished a certain result in one city they need not be expected to accomplish the same results in any other city is eminently true. Every tub must stand on its own bottom, and while results in one city may be taken as an indication of what may be looked for by a similar treatment in other places, a study of conditions prevalent in each city must be made and its salvation worked out independently. In working out the effect of meters upon the consumption of water in any city, and especially in doing this comparatively among different cities, we are at once confronted by the paucity of statistical records. Many very indefinite quantities enter into the problem. For instance, in a city of any considerable size, the non-resident and floating population is an element to be considered. It will be remembered that when Mr. Nicholas S. Hill, as chief engineer of the water department of New York, was making elaborate water-waste surveys in that city, he found in certain sections what appeared to be enormous waste. When an analysis of the population and business enterprises of these sections was made, however, it was found that including the non-resident population the consumption was, in reality, remarkably low.

If my recollection is not at fault, the statement made at that time was that the floating population of Greater New York was estimated at between 500 000 and 600 000. In my own city, after a good deal of investigation, I am accustomed to call the non-resident population equivalent to 3 000 regular water consumers.

* Distribution Engineer, Hartford Water Works, Hartford, Conn.

Another common source of error in pumped supplies, where the rated capacity of the pumps is the only means of measurement, is in making wrong allowances for slip.

Where a large percentage of the taps are metered there is danger of arriving at wrong conclusions on account of the under-registration of meters. In my own city not long since, out of 201 meters tested, 31 registered less than 98 per cent. of actual flow, the range of percentages of registration being from 84 to 97.82.

Of the 201 meters above mentioned, 19 registered over 102 per cent. of actual flow, but inasmuch as the worst case exceeded this figure by only 1.73 per cent., it will be seen that the over-registration need hardly be considered.

In figuring upon leakage and waste, sight is lost frequently of private fire-service pipes. In my own opinion, if these were either all metered or subjected to rigid control of some kind, many a water-works department would be able to make a much closer accounting for its water than it now can.

There is no doubt whatever, as Mr. Johnson says, that the first effect of meters when set in considerable numbers is to reduce the consumption. For a short time they seem to frighten the consumer into exercising the greatest care, not only in the necessary use of water, but in keeping plumbing in repair as well. After he receives a few bills under the meter system he is apt to discover that if anything he is paying less than under assessment, and his care at once relaxes, with the result that consumption increases.

That what might be called the necessary consumption of water is increasing, I think there is no doubt. I also doubt if any meter system will reach its highest efficiency in reducing consumption unless coupled with a rigid leak inspection both inside and outside the premises.

Metering of the city of Hartford was begun in 1900 and completed in 1903. According to the best information at my command the per capita consumption before general metering was commenced was about 84.6 gallons. Since that time the average per capita consumption by years has been as follows: 1901, 75.5; 1902, 77.2; 1903, 74.2; 1904, 66.4; 1905, 62.8; 1906, 64.7.

It will be noticed that the most remarkable decrease in consumption occurred in the year following the completion of metering, 1904.

During this year and since that time, however, a very thorough investigation for leaks all over the distribution system has been maintained, which I think accounts for the sudden drop. The consumption of the year 1906 would indicate that in spite of meters and leak inspection, increased use of water is making itself felt.

In this connection, however, I will say that my opinion is that the population of the city has increased much more than we suppose, and that if the true figures were known the apparent per capita would be somewhat reduced.

Mr. Morris Knowles * (*by letter*). The Association is fortunate in having presented so clearly much valuable information regarding this problem which, while it has long been before us, is yet little understood by the mass of the people. The author deserves our thanks for his labor and painstaking care in bringing out important data, some of a novel kind, and the deductions from them.

The writer does not agree with all the conclusions, but neither does he believe, with some, that this article, written with these ideas, will do harm and create a sentiment against metering. There is some popular cry against the use of meters, due to many different causes, but this is not general among those who intelligently look into all phases of the subject, unless political or personal financial reasons cause a bias. The truth cannot hurt, and facts honestly presented and intelligently discussed can operate only for good. If the facts now brought out should indicate that metering is not so valuable as has previously been supposed, no amount of blind following of old dogmas will long keep the proper light hidden; thoughtful consideration is best.

The writer, however, does not believe that the facts show a failure in meters to do that which may properly be expected, namely, to reduce the waste and improper use of water and to prevent an extravagant increase. For a long time many have anticipated too much from metering alone, and it is but reasonable that thoughtful consideration of facts will show that other investigations and rigid inspections should go hand in hand with the general introductions of meters. Furthermore, while the general

* Chief Engineer Bureau of Filtration, Pittsburgh, Pa.

use of water is increasing, due to the several causes mentioned by the author, and most of all due primarily to the prosperity of the country and the general lavish conduct of the American people, waste and excessive increase are checked by the use of meters, especially if other precautionary measures be adopted.

Several years ago, in considering the use of water for the city of Pittsburgh, the writer, in coöperation with Mr. A. B. Shepherd, superintendent of the Bureau of Water, made an estimate of the probable saving that could be made with the introduction of meters and careful restrictive measures and investigations. Considerable criticism developed, due to the fact that the capacity of the filtration works was based upon an ultimate figure of 125 gallons per inhabitant per day, and that the works should be prepared to deliver at first the amount of water then being used. Many persons, believing that two thirds of the water was wasted, thought that the use of 253 gallons per person per day at that time should be brought down to about 85. This is but an example of two great expectations, — a forgetfulness that certain places may naturally use more water than others, and also that works should be designed for that which is rather than for that which should be.

At the time of making these estimates for the city of Pittsburgh, data were secured from most of the cities in this country having more than 25 000 population, and this information was plotted to show the relation between the per cent. of services metered and the daily use of water per inhabitant. This diagram has recently been brought down to date and it is reproduced in Plate II. The most important thing to engage attention is that the recent knowledge does not materially change the general appearance of the diagram. For the purpose of comparison, the average line made up from Mr. Johnson's data for five groups is plotted as RST.

The completed line for the city of Pittsburgh for the last few years is particularly instructive, and it is remarkable and seems almost beyond belief that for the year 1906 the line strikes almost exactly upon the point predicted under normal conditions of introducing meters.

A few words may not be amiss about the slope of this line. It

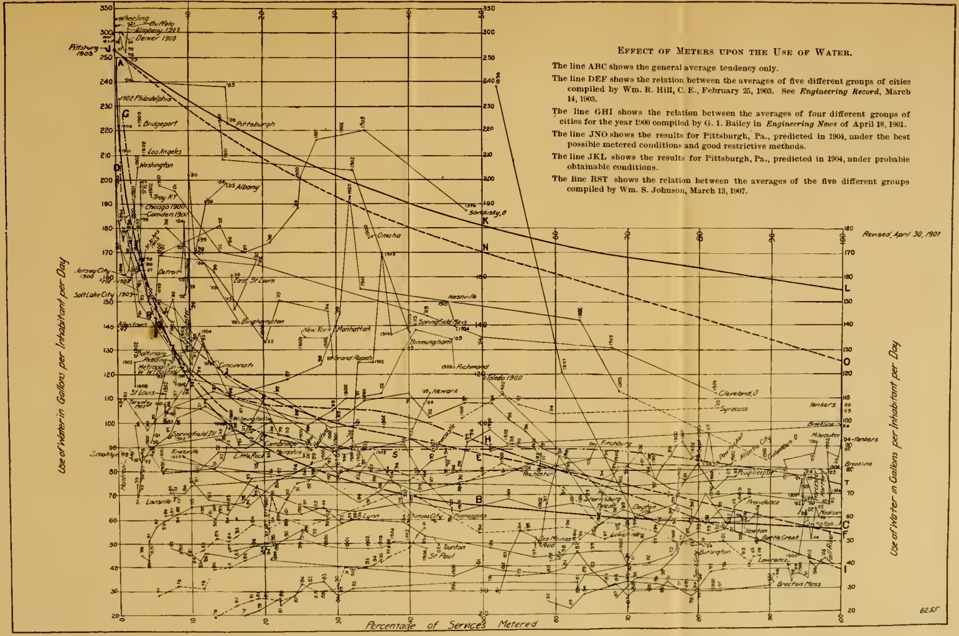
is probable that the 1903 stated use of water was too high; the over-estimate was due to the fact that for a long time the pumps had been working without much rest for overhauling and repairs, and the turbid and gritty water had developed a large amount of wear in the valves, and thus a large amount of slip and an over-estimate of the pumpage. With the addition of two new pumping engines, made available in 1904, and the slip thus reduced, it will be seen that there was a sudden drop in the use of water per person. The new figure was probably the more correct one for the previous year or two. Meters have been introduced, and out of a total number of about 6 500, very nearly one third are in one district, using one twentieth of the water. The marked drop during the last year has also, in part, been due to a thorough pitometer investigation and house-to-house inspection, mostly in this same district.

It may be of interest to give the statistics of this district, which is a good example of what can be accomplished, not only with thorough metering, but even after, by a careful study of the losses in the mains and by a house-to-house inspection. This district, which comprises a certain high territory supplied from the Bedford reservoir, is one which is easily separated for this purpose; and by the courtesy of Mr. A. B. Shepherd, superintendent, the writer is enabled to present this valuable information. It should be remembered, however, that while meters have been largely introduced, payment is still made at the fixture rate, there being no ordinance compelling the purchase of the water by meter. The following are the statistics of this district:

Size of the Bedford District	286 acres.
Population, estimated to be the same as at the census of 1900	27 241 persons.
Population supplied through meters	16 800 persons.
Number of houses	3 773
Number of services	2 580
Average population per house	7.2 persons.
Average population per service	10.5 persons.
Water mains in the district	13.5 miles.
Population per mile of main	2 016 persons.
Services per mile of main	191

Character of district, tenements; plumbing, old and generally poor.

Daily quantity of water entering the district at beginning of the investigation, August 1, 1906 .... 4 325 000 gallons.


EFFECT OF METERS UPON THE USE OF WATER.
The line ABC shows the general average tendency only.
The line DEF shows the relation between the averages of five different groups of cities compiled by Wm. R. Hill, C. E., February 25, 1903. See *Engineering Record*, March 14, 1903.
The line GHI shows the relation between the averages of four different groups of cities for the year 1900 compiled by G. I. Bailey in *Engineering News* of April 18, 1901.
The line JNO shows the results for Pittsburgh, Pa., predicted in 1904, under the best possible metered conditions and good restrictive methods.
The line JKL shows the results for Pittsburgh, Pa., predicted in 1904, under probable obtainable conditions.
The line RST shows the relation between the averages of the five different groups compiled by Wm. S. Johnson, March 13, 1907.
Revised, April 30, 1907
Use of Water in Gallons per Inhabitant per Day
Percentage of Services Metered
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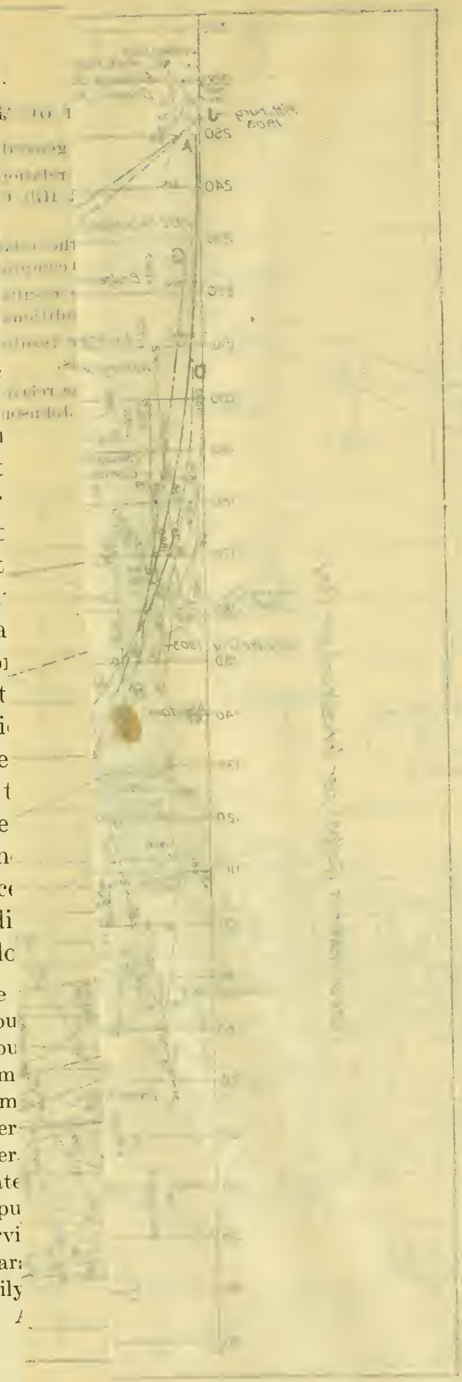

Daily quantity of water entering the districts at close of the investigation, April 19, 1907 .... 3 025 000 gallons.
Saving per day .... 1 300 000 gallons.
Per cent. of water saved 30
Per cent. of services metered 74.8
Per cent. of water measured by meter 43.7
Water used per person per day before investigation .... 158 gallons.
Water used per person per day after investigation .... 111 gallons.

From the known night waste it is estimated that one third of the 111 gallons is still a constant loss.

In Fig. 14 there is shown, in a graphical way, the results in this same Bedford district, showing the decrease in the use of water per inhabitant, month by month, and the corresponding increase in the per cent. of services metered. The latter months of the diagram show the further decrease, as detailed in the above tabulation, with the per cent. of services metered remaining the same.

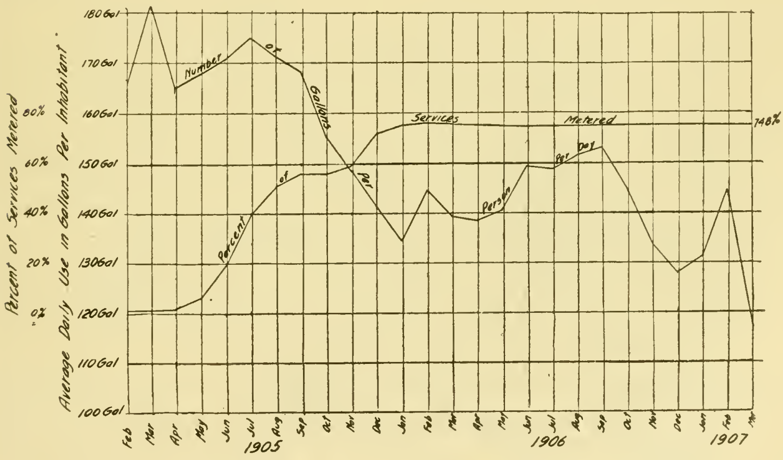

FIG. 14. EFFECT OF METERING AND INVESTIGATION WORK IN BEDFORD DISTRICT, PITTSBURGH, PA.

As a further study into the problem of what metering means to cities, we have plotted, in Figs. 15 and 16, results from various cities in the country. These are divided into two groups; Fig. 15 contains those in which less than 15 per cent. of the services

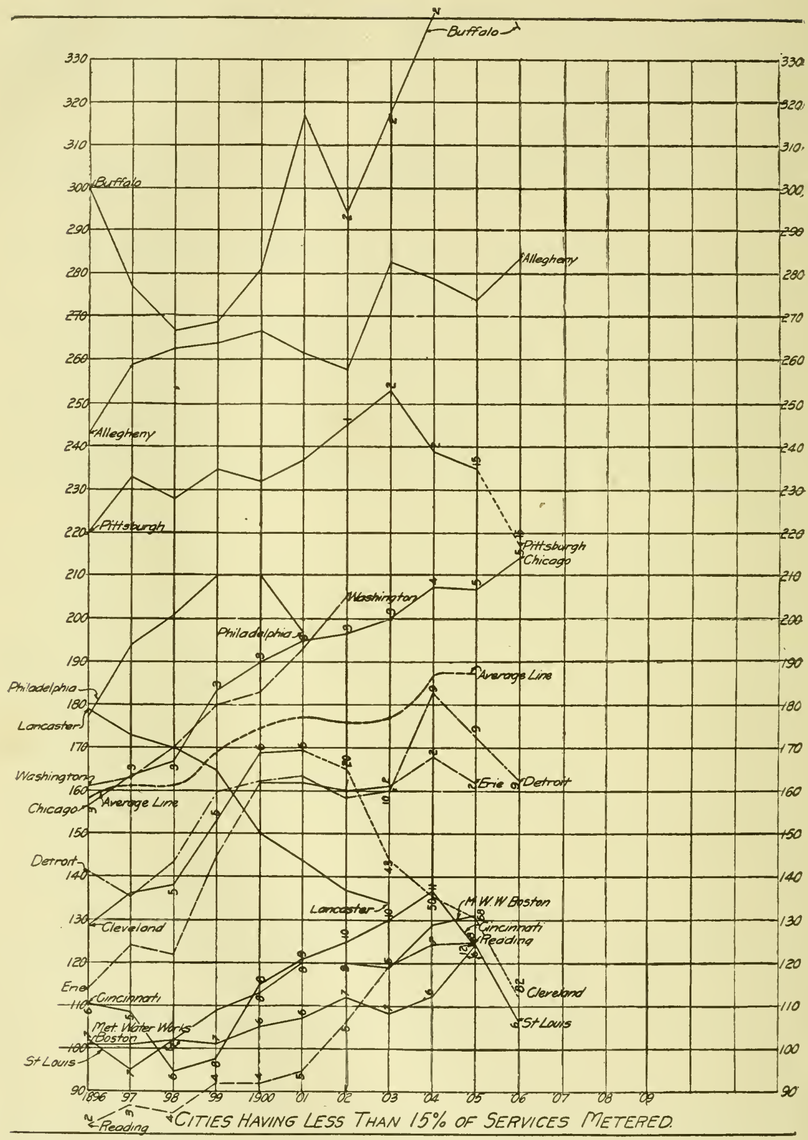

FIG. 15. FLUCTUATIONS IN THE PER CAPITA USE OF WATER IN CITIES WITH SMALL PERCENTAGES OF SERVICES METERED.

are metered; and Fig. 16 those in which more than 50 per cent. of the services are metered.

The most striking result is the very large consumption in the first group and also the erratic behavior of the lines, showing probably that spasmodic efforts have operated to reduce the

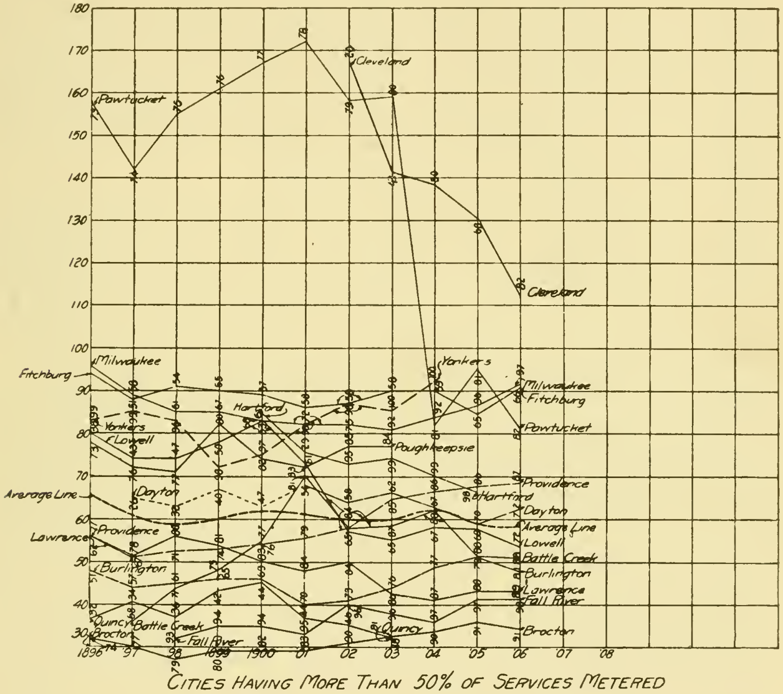

Fig. 16. Fluctuations in the Per Capita Use of Water in Cities with Large Percentages of Services Metered.

waste. In the second group it is to be noticed that the use of water is low, with two exceptions, and the lines follow about the same course, showing but little increase, if any.

The average line in the first group increases 29 gallons in ten years, while the average line of the second group decreases 8 gallons in the eleven years. The latter does not include the effect of the two erratic cities at the top of the diagram. This would

seem to give other evidence than that shown upon Mr. Johnson's Fig. 1. The writer, however, does not pretend to say that metering alone will always cause a reduction, or that, without increasing the use of meters, the line of the use of water will not have a general tendency upward. Eternal vigilance is the price to pay for curtailing waste and keeping an increase in the use of water, as well as other commodities, within reasonable limits.

There is one important factor shown by all of these recent investigations, and that is, that meters do not curtail a reasonable use of water for ordinary household purposes. It is important to dwell upon this because the advocate of meters frequently meets with opposition from this standpoint.

Mr. Johnson has advanced the novel claim that where water is of good quality, there will be less used. This is worth considering, and the writer has already called attention to the fact that, where water is muddy and gritty, there may be another reason for apparent excess, due to excessive slip, which is not always properly estimated and frequently not high enough.

The writer cannot agree that the winter waste is negligible, nor is it true that all cities will show the same months for increase as that shown for Massachusetts in Mr. Johnson's Table No. 6, page 129. A similar statement for Pittsburgh is given in Table No. 13. Another truth is not shown, namely, that the days of largest pumpage are frequently in the winter time.

One of the last items mentioned, namely, that the per cent. of water accounted for is small, has always been a startling revelation to those who have investigated this matter. It shows that there are likely to be places of large waste besides the house plumbing, and this is a strong argument for other means of investigation and for large meters upon the principal water mains supplying given districts, so that the total quantities coming into a district can be determined.

The writer is glad to heartily concur in the closing paragraphs of the author, and to express the belief that by the dissemination of such data we will come to a more thorough understanding of this interesting problem.

TABLE No. 13.

PER CENT. WHICH MONTHLY USE OF WATER IS OF THE AVERAGE, TOGETHER WITH AVERAGE RAINFALL AND TEMPERATURE FOR PITTSBURGH.
(AVERAGE OF ELEVEN YEARS, 1896–1906.)

	Per Cent. of Average Use of Water.	Rainfall. Inches.	Temperature, Degrees Fahr.
January	98.8	2.14	31.1
February	103.8	2.29	29.0
March	101.3	3.90	41.4
April	99.1	2.96	51.2
May	97.7	3.03	63.9
June	99.5	4.61	70.5
July	102.0	3.99	75.3
August	102.3	2.94	73.4
September	102.0	2.14	67.6
October	98.7	2.29	56.5
November	96.4	2.22	44.1
December	99.7	2.63	33.3

MR. JOHNSON (*by letter*). Judging from some of the foregoing discussions, certain of the conclusions in my paper cannot have been clearly stated. I have not attempted to show, nor have I suggested, that meters do not reduce the waste of water in houses. What I have shown is rather that high consumption does not necessarily mean wastefulness on the part of the consumer, and that it cannot, in all cases at least, be reduced to a low figure by the introduction of house meters. I am very far from condemning meters as being worthless, but rather would condemn the extravagant claims made as to what they will accomplish.

It is unfortunate that in order to secure the introduction of meters, water-works officials so often find it necessary to make claims as to the great economy in their use which cannot be substantiated. As a matter of fact, there are much better reasons why meters should be used than the mere reduction in the consumption of water, and even if it is found to be cheaper, as in some cases it will be, to supply the excessive quantity of water wasted than to install and maintain meters, yet the use of meters is justified in order that the cost of the water may be equitably assessed. Mr. Richards has expressed this very well in his discussion.

In an effort to accomplish a reform we are too apt to see only those facts which are favorable, shutting our eyes to those less favorable. The cases of Fall River and Brockton are always cited, but we seldom have brought to our attention the many cases where meters are in general use but the consumption remains high. In this paper all of the places concerning which information could be obtained have been included and the facts are presented for what they are worth.

Mr. Brackett in his discussion has unconsciously emphasized the point which I have tried to make in regard to dangers in the selection of certain facts while ignoring others which are equally applicable. He speaks of the high winter consumption in the cities of Boston and Chelsea, which are practically unmetered, and compares the consumption in these places with the low winter consumption in the metered towns of Belmont, Malden, Milton, and Watertown. That the low winter consumption in the latter places is not due to meters alone can be shown by a comparison with the consumption in other cities in the Metropolitan District where meters are not used and yet there is no excessive consumption in winter. The following table is introduced to supplement Mr. Brackett's table by giving *all* the facts. The figures are taken from Mr. Brackett's discussion.

	Per Cent. Services Metered, 1906.	Average Nov. and April, 1906 (Gallons).	Average Four Winter Mos. in 1906 (Gallons).
Boston	5	143	160
Somerville	19	82	88
Malden	78	49	50
Chelsea	10	87	109
Everett	2	73	86
Quincy	3	99	104
Medford	8	93	94
Melrose	3	106	109
Revere	4	67	75
Watertown	93	66	60
Arlington	22	74	73
Milton	100	42	38
Winthrop	2	97	102
Stoneham	2	67	64
Belmont	100	53	44
Lexington	2	71	61
Nahant	18	71	69
Swampscott	0	73	74

Mr. Brackett's statement that in places having a population of less than 50 000 the average per capita consumption should not exceed 50 gallons I will not dispute, but the fact remains that it *does* exceed this amount, and even in the Metropolitan District, as shown by Mr. Brackett's table, there is only one town having a consumption less than 50 gallons per person per day. Furthermore, as stated in the paper, the use of water is increasing at a rapid rate notwithstanding the use of meters, and we must face the fact that if the consumption is to be reduced to 50 gallons per person, it will not be by the use of domestic meters alone. As Mr. Knowles has said, "Works should be designed for that which *is* rather than that which *should be.*"

Mr. James H. Fuertes, in his recent report to the Merchants' Association of New York, has made an excellent analysis of the use and waste of water in New York City, and his conclusion is that while a much larger quantity of water is wasted in various ways, the maximum reduction which can be expected by the general use of meters is 15 gallons per person per day. This I am convinced is a reasonable figure to apply to the average unmetered city where the consumption is from 75 to 100 gallons and where there are no unusual conditions.

The point raised by Mr. Sherman as to the increase in the per capita use of water with the age of the works is a good one, and the following table, giving the average consumption in a large number of places, is presented to show the rapid increase in the use of water in the years immediately after the construction of works, due probably in a large measure to the increase in the number of consumers:

TABLE SHOWING INCREASE IN CONSUMPTION OF WATER, WITH AGE OF WORKS.

Year after Water was Introduced.	Consumption. Gallons per Person per Day.
1	22
2	27
3	34
4	36
5	40
6	40
7	38
8	41
9	41
10	42

Mr. Whitney has suggested the effect of the introduction of sewers upon the consumption of water, and the following table is presented which gives the best data which I have been able to obtain in regard to this. The difficulty in collecting such data is that in most cases the sewerage system is of gradual growth, and there are few places where it can be said that in a certain year a complete sewerage system was introduced.

TABLE No. 14.

CONSUMPTION OF WATER IN FIVE CITIES AND TOWNS BEFORE AND AFTER THE INTRODUCTION OF A FAIRLY COMPLETE SYSTEM OF SEWERS. (GALLONS PER PERSON PER DAY.)

City or Town.	Year Previous to Introduction of Sewers.							Year when Sewer System was Practically Completed.	Year Subsequent to Introduction of Sewers.						
	7	6	5	4	3	2	1		1	2	3	4	5	6	7
Marlborough	13	17	20	21	24	24	25	26	30	30	35	34	37	37	38
Newton	28	31	33	33	31	36	40	42	50	52	60	65	63	60	57
Waltham	37	36	39	33	31	32	33	40	47	53	61	59	71	70	76
Natick	27	29	34	37	40	41	43	46	41	40	42	40	38	42	51
Woburn	60	51	58	54	56	65	69	73	72	68	70	78	78	82	85
Average	33	33	37	36	36	40	42	45	48	49	54	55	57	58	61

A NOTE ON THE SPONTANEOUS IGNITION OF GAS FROM SEWAGE.

BY PROF. W. P. MASON, DEPARTMENT OF CHEMISTRY, RENSSELAER POLYTECHNIC INSTITUTE, TROY, N. Y.

[*Contributed April 17, 1907.*]

At the time of presenting my suggestion that phosphine was probably the agent that ignited the gas mixture in the Saratoga septic tank, which resulted in an explosion that wrecked the structure,* I was not possessed of any data in support of the proposition excepting my observation of gas bubbles which burst into flame as they escaped from the water off the New York docks. I am now in receipt of a letter from Mr. J. H. Fewell, superintendent of the Water Company at Jackson, Miss., in which he says:

"Through the kindness of some fellow member of the American Water Works Association I received a copy of the proceedings of the New England Water Works Association and carefully read your article in reference to the cause of the explosion which wrecked the septic tank at Saratoga, N. Y. It seemed from the discussion which followed that some of your fellow members were a little in doubt as to the correctness of your theory. Some time ago I was out on Pearl River near this city and near our pumping station. There I witnessed a very curious phenomenon. I observed some distance from the shore a great many very large bubbles which came rushing up from below, and when each one reached the surface it burst and a greenish flame would shoot up several inches. I watched it for quite a period of time and was much interested to know about the cause and to have it explained to me, so your theory is timely."

This would seem like some confirmation of my contention. Doubtless the phenomenon occurs but seldom, because of adverse conditions, and one might readily grow weary of watching for it at a sewer outfall, but such an occurrence is apparently not unknown, and it is the part of wisdom to bear in mind the possibility of its happening.

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* JOURNAL N. E. WATER WORKS ASSOCIATION, March, 1907, p. 23.

PROCEEDINGS.

March Meeting.

Hotel Brunswick,
Boston, March 13, 1907.

The March meeting of the Association was held at the Hotel Brunswick, Boston, at 2 p.m., on Wednesday, March 13, 1907.

President John C. Whitney presided, and the following members and guests were in attendance:

Members.

S. A. Agnew, C. H. Baldwin, L. M. Bancroft, F. A. Barbour, J. W. Blackmer, C. A. Bogardus, George Bowers, Dexter Brackett, G. A. P. Bucknam, George Cassell, C. E. Chandler, J. C. Chase, C. E. Childs, R. C. P. Coggeshall, M. F. Collins, W. R. Conard, A. W. Cuddeback, L. E. Daboll, John Doyle, H. P. Eddy, I. T. Farnham, F. F. Forbes, A. N. French, F. L. Fuller, E. F. Garvey, J. C. Gilbert, A. S. Glover, X. H. Goodnough, F. W. Gow, E. H. Gowing, R. A. Hale, J. O. Hall, G. W. Hawkes, T. G. Hazard, Jr., J. L. Howard, W. S. Johnson, E. W. Kent, Willard Kent, G. A. King, Morris Knowles, C. F. Knowlton, E. E. Lochridge, A. R. McCallum, H. V. Macksey, N. A. McMillen, D. E. Makepeace, A. E. Martin, John Mayo, F. E. Merrill, William Naylor, O. E. Parks, C. A. Perkins, H. E. Perry, W. H. Richards, L. C. Robinson, Ransome Rowe, H. E. Royce, A. T. Safford, H. W. Sanderson, A. L. Sawyer, E. M. Shedd, C. W. Sherman, G. H. Snell, G. A. Stacy, W. F. Sullivan, L. A. Taylor, R. J. Thomas, W. H. Thomas, J. L. Tighe, J. A. Tilden, D. N. Tower, C. A. Townsend, W. H. Vaughn, C. K. Walker, R. S. Weston, J. C. Whitney, F. I. Winslow, G. E. Winslow. — 79.

Associates.

Harold L. Bond Company, by Harold L. Bond; Builders Iron Foundry, by F. N. Connet; Coffin Valve Company, by H. L. Weston; The Fairbanks Company, by F. A. Leavitt; Hersey Manufacturing Company, by Albert S. Glover, J. A. Tilden, W. A. Hersey, and H. V. Macksey; International Meter Company, by Samuel Harrison; Lead Lined Iron Pipe Company, by Thomas E. Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould; H. Mueller Manufacturing Company, by George A. Caldwell; National Meter Company, by Charles H. Baldwin and J. G. Lufkin; Neptune Meter Company, by H. H. Kinsey; The Platt Iron Works Company, by F. H. Hayes; Rensselaer Manufacturing Company, by F. S. Bates and C. L. Brown; A. P. Smith Manufacturing Company, by Fred N. Whitcomb; Thomson Meter Company, by Edward M. Shedd; Union Water Meter Company, by F. E. Hall and F. L. Northrop;

United States Cast Iron Pipe and Foundry Company, by Frank W. Nevins; R. D. Wood & Co., by William F. Woodburn. — 24.

GUESTS.

James G. Hill, water commissioner, Lowell, Mass.; E. T. Harvell, water commissioner, Rockland, Mass.; C. D. Baker, superintendent, Abington, Mass.; C. W. Gilbert, and William E. Blodgett, Mayor, Woburn, Mass.; Sumner W. Hildreth, engineer, Westfield, Mass.; J. B. F. Breed, Esq., chief engineer, Commissioners of Sewerage, Louisville, Ky.; William A. Breed, superintendent, Norwich, Conn.; Major E. S. Horton, Carl G. Kritson, Attleboro, Mass.; Mr. George W. Stiles, superintendent, and Charles T. Hall, water commissioner, Malden, Mass.; F. L. Clapp, superintendent, Stoughton, Mass.; E. H. Palmer, Reading, Mass.; A. E. Blackmer, Plymouth, Mass.; J. B. Newhall, Stapleton, S. I. — 16.

[Names counted twice — 7.]

THE PRESIDENT. We have a guest with us who has consented to address us briefly. I have the pleasure of introducing Mayor Blodgett of Woburn.

MAYOR WM. E. BLODGETT. I have had occasion in my life sometimes to feel the influence at the polls and elsewhere of the liquor dealers' association, but this is the first time that I have ever come under the influence of the water dealers' association; but so far as my experience goes I would prefer the water cure to the other.

I suppose I am called upon here as a sort of a horrible example. Last year my friend Mr. C. W. Gilbert, who has conceived it to be his function in life to convert me and to bring the city of Woburn around to what he considers real righteousness in the serving of water, brought in to us a horde of fellows to tell us that we knew nothing, and they demonstrated that to their own satisfaction; the chief among them is my friend Mr. Whitney, your President. For months I sought in vain for an opportunity to get back at him, but a certain article in the Boston *Herald*, just prior to my own inauguration, led me to look into some things in his own city; and I had occasion, to my own satisfaction at least, to even up with him. The particular grievance he has got against us is that we do not have any meters, and we have no use for water meters, and we have never had any lack of water, except to give a banquet to them, such as I have had with you to-day.

I congratulate you on the work that you are doing.

Mr. E. H. Gowing. Mr. President, two months ago I was down in New Orleans and there I met a man whom many of you know, Colonel Gardiner. I have a recollection of a speech that he made in Boston some years ago at a meeting of the American Water Works Association. He wished me when I got back to remember him cordially to all those he knew and who knew him.

Mr. Wm. S. Johnson, assistant engineer, Massachusetts State Board of Health, read a paper entitled "Some New Facts Relating to the Effect of Meters on the Consumption of Water." It was discussed by Messrs. George A. King, Charles W. Sherman, Walter H. Richards, Dexter Brackett, R. J. Thomas, Frank L. Fuller, George Cassell, F. H. Hayes, Henry V. Macksey, J. C. Gilbert, X. H. Goodnough, and Mr. Johnson.

On account of the lateness of the hour the paper by Mr. F. A. Barbour, which had been announced for this meeting, was, with Mr. Barbour's consent, postponed until the September meeting.

The Secretary read applications for membership from the following persons:

William W. Lewis, water commissioner, Hyde Park, Mass.; Samuel W. Hoyt, Jr., resident engineer, Water Filtration Plant, South Norwalk, Conn.; George A. Nelson, assistant city engineer on Water Works, Lowell, Mass.; Howard M. King, assistant engineer, Water Department, Springfield, Mass.; Leland G. Carlton, Springfield, Mass.; Walter Wood, treasurer, engineer, and manager, Millville, N. J., and Owego, N. Y., water companies, Philadelphia, Pa.; S. E. Killam, Reading, Mass.; John C. DeMello, general foreman Distributing Department, New Bedford Water Works, New Bedford, Mass.; David S. Rundlett, superintendent Water Works, Watertown, Mass.; Edward L. Hatch, general manager Stamford Water Company, Stamford, Conn.,

all of whom had been recommended for election by the Executive Committee.

On motion the Secretary was authorized to cast a ballot for the Association in favor of the applicants, which he did, and they were declared elected to membership.

The meeting then adjourned.

EXECUTIVE COMMITTEE.

BOSTON, MASS.,
March 13, 1907, 11.30 A.M.

Present: President J. C. Whitney, and members George W. Batchelder, L. M. Bancroft, R. J. Thomas, D. N. Tower, George A. King, A. E. Martin, George H. Snell, Charles W. Sherman, and Willard Kent.

Ten applications for membership were received and recommended for admission.

The record of the last meeting of the Executive Committee was read and approved.

Application received and laid on the table at last meeting of the Executive Committee was discussed without action.

Committee on June excursion reported in favor of Gloucester, Mass. Report was accepted and committee continued.

On motion of Mr. Bancroft, seconded by Mr. Snell, the President, Editor, and Secretary were made a Committee on Publicity.

Six members previously dropped for non-payment of dues were by vote reinstated, their dues having been paid in full.

Place of next annual convention was discussed without action.

Voted: That the President and Secretary be a Committee on Hotel Accommodations for the next winter meetings.

Adjourned.

WILLARD KENT, *Secretary.*

OBITUARY.

Valentine C. Hastings, vice-president of the Association, and superintendent of the Concord, N. H., Water Works, died at his home in that city on March 14, 1907.

He was born in Waterford, Vt., February 26, 1838. In 1867 he entered the employment of the Cement-Lined Water Pipe Co. of Springfield, Mass. In 1869 he took charge of a similar company in Manchester, N. H., and a short time later he went to Concord to superintend the construction of the water works system. In April, 1873, he was elected superintendent of the Concord Water Works, and held that position until his death. His ability and fidelity are attested by the long period of service in this office.

Mr. Hastings had at various times held a number of positions of trust and honor in business and church circles, and was a member of the state legislature in 1887. He leaves a wife, three daughters, and one son. The Concord *Daily Patriot* said of him: "As a good citizen and a man of steadfast friendship he will be greatly missed."

Mr. Hastings was elected a member of this Association on June 10, 1886. He served as one of the vice-presidents several years ago, and was again elected to that office at the last annual meeting.

Myron Edward Evans, C.E., president of the Cape Breton Railway of Canada, was killed in the wreck on the New York Central & Hudson River Railroad at Bronx Park, New York City, on February 16, 1907.

Mr. Evans had an office in New York City and was on his way to his home in White Plains, N. Y., when the accident occurred. He was a graduate of the Rensselaer Polytechnic Institute, Class of 1895, and was an associate member of the American Society of Civil Engineers. He was elected a member of the New England Water Works Association June 13, 1900.

John F. J. Mulhall, water-works accountant and treasurer of several water companies, died on June 9, 1907, following an operation for appendicitis.

Mr. Mulhall was born in Boston on December 3, 1862. He was graduated from the Boston English High School in 1880. His first employment was as clerk in the Boston Railroad Clearing House. Later he studied shorthand under the Hon. Stephen O'Meara, the present police commissioner, then editor of the Boston *Journal.* For some years he was in the office of the Boston Water Board, and in 1885 entered the employ of Wheeler & Parks, engineers and operators of water companies. After the dissolution of that firm Mr. Mulhall remained with Mr. William Wheeler as accountant, and was treasurer of several of the water companies of which Mr. Wheeler is general manager. More recently he had also done private work as an expert accountant. In 1906 he published a book entitled "Quasi-Public Corporation Accounting and Management."

Mr. Mulhall was a member of the Boston Common Council in 1889 and 1890. He is survived by a wife and ten children.

He was elected a member of the New England Water Works Association, November 14, 1900.

BOOK REVIEWS.

The Value of Pure Water. By George C. Whipple. viii + 84 pp. $5\frac{1}{2}$ x 8 inches. New York: John Wiley & Sons. $1.00.

This little book unquestionably fills a long-felt want. It represents an attempt to express in terms of dollars and cents the depreciation suffered by a contaminated or otherwise objectionable water in comparison with one which is absolutely pure and unobjectionable.

As the author says in his preface, "The financial standard is certainly not the highest one for judging the quality of a water supply when the public health is concerned; human life cannot be estimated in gold dollars, and the smell of unsavory water to a thirsty man cannot be reckoned in dimes; nevertheless, the financial basis is a convenient one, and one necessarily involved in all questions which relate to public utilities."

No one is more competent than Mr. Whipple to speak upon this subject with authority, as is well known to the members of this Association. The matter is presented in Mr. Whipple's usual clear and logical style, and is so well presented that it makes a very readable as well as a very valuable book.

Outlines of Practical Sanitation. By Dr. Harvey B. Bashore, Inspector for Pennsylvania Department of Health. vi + 208 pp. 5 x $7\frac{1}{2}$ inches. New York: John Wiley & Sons. $1.25.

This is a very interesting little book for the general reader and contains much valuable sanitary information. One chapter of twenty-five pages is devoted to water supply. This is probably as much space as proportionally belongs to this subject in a book of this size on general sanitation. The importance of sanitary surveys of watersheds is clearly set forth, and the sanitary significance of various substances in or properties of water are well presented.

Water-Works Management and Maintenance. By Winfred D. Hubbard and Wynkoop Kiersted. vi + 429 pp. 6 x 9 inches. Many illustrations. New York: John Wiley & Sons. $4.00.

A book on water-works operation and maintenance has been needed for a long time, and it is therefore a pleasure to welcome this work, which contains a great deal of data not otherwise available except, for the most part, in the Journal of this Association and in engineering periodicals.

The contents are: Part I — On the Methods and Principles of Developing, Improving, and Storing Water Supplies: Ground Water Supply; River-water Supply; Pumping Engines; Impounded Supplies. Part II — Maintenance and Operation: Plans and Records; Extensions; Service Connections; Meters; Care of Appurtenances; Alterations and Repairs; Maintenance of Quality; Water Waste; Electrolysis; Fire Protection; Accounts; Financial Management; Rules and Regulations; Annual Reports. Part III — Franchise: Water Rates; Depreciation.

Part I constitutes 217 pages, or more than half of the volume. It has to do almost wholly with the selection of sources of supply, their development and the filtration or other improvement of unsatisfactory waters, subjects previously treated by several writers, and, moreover, relating to matters of design and construction rather than of maintenance and operation of water works. Although the importance of these subjects is fully conceded and the excellence of their treatment in the present volume is not disputed, it seems to the reviewer that they are out of place in this book, or rather that the space devoted to them should not have exceeded 15 to 20 per cent., instead of 50 per cent., of the book.

Passing to Part II, "Maintenance and Operation," the part which gives the book its reason for existence, it is a pleasure to find so much valuable information, and, on the whole, so well arranged. It is out of the question, within the limits of this review, to give a more detailed statement of what the book contains than is presented in the above table of contents, and it may therefore be well to pass to a mention of what, in the reviewer's opinion, are some of the defects of the book.

In the first place, would it not have been wise to make a handbook or "pocket-book," similar to Trautwine, Kent, and Foster, instead of a book of such shape and bulk as to be convenient for library use only?

Although the paper is good and the type clear and sharp, the make-up may be criticised in several points. First and most important, there are practically no sub-headings, and even after looking up a reference in the index,— which, by the way, is a good one, — there is nothing to catch the eye and assist in finding the place. A freer use of bold-faced type and italics would have much improved the book in this particular. When tables or diagrams which are set lengthwise of the page are examined, it is found that some of them read up and others down. Some of the figures are on so small a scale as to render it difficult, if not impossible, to obtain the information which they are intended to convey — witness the cut of the Walker hydrant. Some of the half-tone cuts were made with so coarse a screen as to seriously impair the effect of the illustrations.

Some of the subjects not mentioned which appear well worthy of treatment are the following:

Forestry of watersheds; screens in intake gate houses; durability of asphalt in reservoir linings; anchor ice; painting; standpipes; ice in standpipes; selection of fuel; electrically-operated valves; hydraulic valves; check valves; valve chambers; fire service meters; the importance of measuring the quantity of water supplied to a distribution system, etc.

In spite of these defects, however, the book is a valuable one, and is certain to prove of much use to water-works men.

TRADE PUBLICATIONS.

Allis-Chalmers Company (Milwaukee, Wis.), *Pumping Engine Department.* Bulletin No. 1609, March, 1907. *Official Duty Tests of Pumping Engines Nos. 1, 2, and 3, at Bissell's Point Pumping Station, St. Louis, Mo., Water Works.* Pp. 25. 8 x 10½ inches. Tables and illustrations.

These pumping engines are each of 20 000 000 gallons capacity, of the vertical triple-expansion type, with outside packed single-acting plungers. The tests were made in 1904 and 1905, and showed duties of 176 866 000, 176 094 000, and 181 068 605 foot-pounds, respectively, per 1 000 pounds of steam. The results of the tests are given in detail in the bulletin.

Cast-Iron Pipe. *Some Notes and Tables. Standard Specifications, Dimensions, and Weights of Cast-Iron Bell and Spigot Pipe and Special Castings for Water, Gas, Sewages, Culverts, Drains, etc. Flange Pipe and Special Castings, Flexible Joint Pipe, Loam Castings, Heavy Special Castings.* 1906. New York: United States Cast Iron Pipe and Foundry Company. Pp. 156. 8¾ x 10¾ inches.

This excellent handbook or catalogue contains considerable historical and descriptive matter relating to water conduits, especially cast-iron pipe, with many good illustrations. The standard specifications of the company are given. It is stated that "the standard specifications for cast-iron pipe and special castings will be found to be substantially those of the New England Water Works Association, modified to cover the four classes of pipe shown in our Table No. 2 instead of the ten classes listed in Table No. 2 of the New England specifications, while many of the dimensions in our Table No. 1 are identical with those of the New England Table No. 1." The greater part of the book is devoted to tables of dimensions and weights and other particulars relating to pipes and special castings, data which would be indispensable to any one laying out details of piping to be constructed with these standard castings.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XXI. September, 1907. No. 3.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

WATER-WORKS STATISTICS FOR THE YEAR 1906, IN FORM ADOPTED BY THE NEW ENGLAND WATER WORKS ASSOCIATION.

COMPILED BY CHARLES W. SHERMAN, EDITOR, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

The tables presented herewith contain statistics of forty-three water works, as summarized in their annual reports. These are all municipally owned water works. There are other water works which summarize their statistics, but the compiler has not succeeded in obtaining their reports for the year 1906.

The report of the Committee on Uniform Statistics, containing the form as endorsed for use in the 1901 reports, is printed on page 51 of Vol. XV of the JOURNAL (March, 1902). The page for Financial Statistics was changed by vote of the Association in September, 1902, as reported in the December, 1902, JOURNAL (Vol. XVI, p. 263). Blank forms for use in preparing summaries are printed by the Association, and will be furnished on request.

Previous compilations of statistics may be found in the JOURNAL, as follows:

Statistics for	Reference to Journal.
1886	Vol. I, No. 4, p. 29
1887	Vol. II, No. 4, p. 28
1888 to 1892 inclusive	Vol. VII, p. 225
1893	Vol. IX, p. 127
1894	Vol. X, p. 131
1895–96	Vol. XII, p. 273
1897–99	Vol. XV, p. 65

Statistics for	Reference to Journal.
1900	Vol. XV, p. 367
1901	Vol. XVI, p. 223
1902	Vol. XVII, p. 235
1903	Vol. XVIII, p. 277
1904	Vol. XIX, p. 241

In the various tabulations, statistics are given for the following places and years:

Place.	Year.
Albany, N. Y.	1900
Andover, Mass.	1900
Arlington, Mass.	1900, 1904, 1906
Atlantic City, N. J.	1898, 1900–04
Attleboro, Mass.	1894–1904, 1906
Bay City, Mich.	1886–87, 1893–96, 1900–04
Belmont, Mass.	1902–04, 1906
Beverly, Mass.	1903, 1906
Billerica, Mass.	1899–1904, 1906
Boston, Mass.	1886–94, 1897, 1900, 1903
Bridgeport, Conn.	1904
Brockton, Mass.	1893–1904, 1906
Burlington, Vt.	1886–1904, 1906
Cambridge, Mass.	1900–04, 1906
Chelsea, Mass.	1900–04, 1906
Cleveland, Ohio	1902–04, 1906
Concord, N. H.	1895, 1898, 1900–04
Dover, N. H.	1900
Erie, Pa.	1900
Essex Junction, Vt.	1900
Fall River, Mass.	1886–95, 1897–1904, 1906
Fitchburg, Mass.	1886–92, 1894–1904, 1906
Freeport, Me.	1901
Geneva, N. Y.	1900
Gloucester, Mass.	1906
Harrisburg, Pa.	1906
Haverhill, Mass.	1900, 1904, 1906
Holyoke, Mass.	1886–92, 1897–98, 1900–04, 1906
Hull, England	1900
Ipswich, Mass.	1900
Keene, N. H.	1899–1900, 1903–04
Lawrence, Mass.	1902–04
Leicester, Mass.	1900
Leominster, Mass.	1900
Lewiston, Me.	1900

Place.	Year.
Lowell, Mass.	1886, 1897–1904, 1906
Lynn, Mass.	1888–98, 1900–04, 1906
Madison, Wis.	1900, 1902–04, 1906
Manchester, N. H.	1900
Marlborough, Mass.	1900, 1903–04, 1906
Maynard, Mass.	1901–03
Metropolitan Water Works, Mass.	1900–04, 1906
Middleboro, Mass.	1895–1904, 1906
Middletown, Conn.	1902
Minneapolis, Minn.	1900–04, 1906
Nantucket, Mass.	1900
Nashua, N. H.	1900, 1904
New Bedford, Mass.	1886–1904, 1906
New London, Conn.	1886–1904, 1906
Newton, Mass.	1888–1904, 1906
Norwich, Conn.	1901
Oberlin, Ohio	1893–1904, 1906
Plymouth, Mass.	1886–1904, 1906
Providence, R. I.	1897–1904, 1906
Quincy, Mass.	1893, 1900–01
Reading, Mass.	1893, 1895–1904, 1906
Reading, Pa.	1901–04, 1906
Rochester, N. Y.	1903
St. John, N. B.	1902–03
Salem, Mass.	1900
Sandusky, Ohio	1886
Schenectady, N. Y.	1886, 1900–01
Somerville, Mass.	1900–04, 1906
Springfield, Mass.	1886–1904, 1906
Taunton, Mass.	1886–1904, 1906
Toronto, Canada	1893
Trenton, N. J.	1886–87
Troy, N. Y.	1886, 1888–93, 1897–99
Waltham, Mass.	1886–1904, 1906
Ware, Mass.	1886, 1888–92, 1900–04, 1906
Watertown, Mass.	1900
Wellesley, Mass.	1888–93, 1898–1904, 1906
Westerly, R. I.	1902–04, 1906
Whitman, Mass.	1897–1904, 1906
Wilmington, Del.	1900
Winchendon, Mass.	1900–04, 1906
Woburn, Mass.	1900–04
Woonsocket, R. I.	1886–1900, 1902–04, 1906
Worcester, Mass.	1900, 1906
Yonkers, N. Y.	1893–96, 1900–04, 1906

1906. — TABLE 1. — GENERAL AND PUMPING STATISTICS.

Number.	Name of city or town.	Date of construction of works.	By whom owned.	Source of supply.	Mode of supply	1	2. — Description of fuel used.				
						Builders of pumping machinery.	a Kind.	b Brand of coal.	c Av. price per gross ton.	d Per cent. of ash.	e Wood. Price per cord.
1	Arlington, Mass.	1872 1894	Town.	Metropolitan W.W.	....	....	....	....	....	..	....
2	Attleboro, Mass.	1873	Town.	Well.	Pumping.	Deane, Barr.	Bituminous.	Georges Cr.	....	..	....
3	Belmont, Mass.	1887	Town.	Metropolitan W.W.	....	....	....	....	....	..	....
4	Beverly, Mass.	1869 1886	City.	Wenham Lake, Longham Res.	Pumping.	Holly.	Bituminous.	Georges Cr.	$3 74	11.2	....
5	Billerica, Mass.	1898	Town.	Driven Wells.	Pumping.	Barr.	Bituminous.	New River.	4 85	..	....
6	Brockton, Mass.	1880 1902	City.	Silver Lake.	Pumping.	Barr.	Bituminous.	New River.	4 90	10.6	....
7	Burlington, Vt.	1867	City.	Lake Champlain.	Pumping.	Worthington.	Bituminous.	....	3 50	..	....
8	Cambridge, Mass.	1855	City.	HobbsBrook, Stony Brook, Fresh Pond.	Pumping.	Groshon, Worthington, Blake.	Bituminous.	Quemahoning Orenda.	3 70 4 00 4 30	.. .. ..	....
9	Chelsea, Mass.	1867	City.	Metropolitan W.W.	....	....	....	....	....	..	....
10	Cleveland, Ohio.	1856	City.	Lake Erie.	Pumping.	Worthington, Knowles, Allis, Kilby, Holly.	Bituminous.	Pittsburg Slack.	1 85	..	....
11	Fall River, Mass.	1874	City.	N. Watuppa Lake.	Pumping.	Worthington, Davidson.	Bituminous.	Cumberland, Georges Cr.	....	..	....
12	Fitchburg, Mass.	1873	City.	Storage Reservoirs.	Gravity.	....	....	....	....	..	....
13	Gloucester, Mass.	1884	City.	Reservoirs.	Pumping.	Knowles, Barr.	Bituminous.	Georges Cr.	5 00	8.5	....
14	Harrisburg, Pa.	1843	City.	Susquehanna R. (filtered).	Pumping.	Barr, Harrisburg.	Anthracite.	Pea.	1 25	17	....

15	Haverhill, Mass.	..	City.	Ponds.	Gravity and Pumping.	Worthington, Deane, Barr.	Bituminous.	Cumberland, Carbon.	$5 16	10	....
16	Holyoke, Mass.	1873	City.	Lakes and Res'v's.	Gravity.	....	....	....	....	..	....
17	Lowell, Mass.	1870	City.	Driven Wells.	Pumping.	Morris, Worthington, Deane, Knowles.	Bituminous.	Pocahontas, Argyle, New River.	5 02	..	....
18	Lynn, Mass.	1871	City.	Ponds and River.	Pumping.	Leavitt, Loretz.	Bituminous.	Georges Cr.	....	13.1	....
19	Madison, Wis.	1882	City.	Artesian Wells.	Pumping.	Allis-Chalmers, Knowles.	Anthracite.	Pea.	4 52	..	....
20	Marlboro, Mass.	1883	City.	Lake and Res.	Pumping.	Blake, Worthington, Barr.	Bituminous.	Various.	5 05	..	....
21	Metropolitan Water Works, Mass.	1848 1872 1895	State of Massachusetts.	L. Cochituate, Sudbury River, Nashua River.	Pumping, 73%. Gravity, 27%.	*Chestnut*	*Hill High*	*Service Stat'n*			
						Holly, Quint'd Allis.	Bituminous.	Quemahoning, Orenda, Georges Cr., Cumberland, Peerless, Miller V., Vulcan, Carbon.	4 09 to 4 79	11.9	....
							Anthracite.	Buckwheat, Screenings.	2 93 2 52		
						Chestnut Hill	*Low Service*	*Station.*			
						Holly.	Bituminous.	Quemahoning, Orenda, Carbon.	4 00 to 4 42	13.4	....
							Anthracite.	Buckwheat, Screenings.	2 84 2 52		
						Spot	*Pond*	*Station.*			
						Blake, Holly.	Bituminous.	Georges Cr., Cumberland.	4 35 to 4 38	12.9	....
							Anthracite.	Screenings.	2 24		
22	Middleboro, Mass.	1885	Fire Dist.	Well.	Pumping.	Deane.	Bituminous.	Pocahontas.	4 58	..	....
23	Minneapolis, Minn.	1868	City.	Mississippi River.	Pumping.	Worthington, Holly.	Sawdust and edgings. Coal.	....	3 27	..	$1 35

1906.—TABLE 1, *Continued.*—GENERAL AND PUMPING STATISTICS.

Number.	Name of city or town.	Date of construction of works.	By whom owned.	Source of supply.	Mode of supply.	1	2.—Description of fuel used.				
						Builders of pumping machinery.	a Kind.	b Brand of coal.	c Av. price per gross ton.	d Per cent. of ash.	e Wood. Price per cord.
24	New Bedford, Mass.	1866	City.	Ponds.	Pumping.	Dickson.	Bituminous.	Georges Cr. Pocahontas.	$4 61 4 64	7	....
25	New London, Conn.	1872	City.	Lake and Res.	Gravity and Pumping.	....	....	....	....	..	....
26	Newton, Mass.	1876	City.	Collecting Gallery.	Pumping.	Barr, Worthington.	Bituminous. Anthracite.	Georges Cr., New River. Screenings.	4 20	14	$6 00
27	Oberlin, Ohio.	1887	Village.	E.Br., Vermillion R.	Pumping.	Deane.	Bituminous.	Pocahontas.	4 10	..	....
28	Plymouth, Mass.	1855	Town.	Ponds.	Gravity and Pumping.	Barr, Worthington.	Bituminous.	Various.	5 00	..	....
29	Providence, R. I.	1870	City.	Pawtuxet River. (filtered.)	Pumping.	Allis-Chalmers. Worthington. Corliss. Holly. Nagle.	Bituminous. Bituminous. Bituminous. Anthracite. Anthracite.	New River. New River. New River. Buckwheat. Buckwheat.	4 17 4 17 4 17 3 23 3 23	8.9 7.3 11.4 20.0 16.2	4 50 4 50 4 50 3 50 3 50
30	Reading, Mass.	1891	Town.	Filter Gallery.	Pumping.	Blake.	Bituminous.	Carbon Fge.	5 70	..	....
31	Reading, Pa.	1819	City.	Creeks and Springs.	Gravity and Pumping.	Worthington, Allis-Chalmers.	Bituminous.	....	2 63	9.4	3 50
32	Somerville, Mass.	1868	City.	Metropolitan W.W.	....	....	....	....	....	..	....
33	Springfield, Mass.	1864	City.	Reservoirs.	Gravity.	....	....	....	....	..	....
34	Taunton, Mass.	1876	City.	Ponds.	Pumping.	Holly, Allis.	Bituminous.	Georges Cr. Cumberland.	5 15 4 50 & 4 65	..	....

35	Waltham, Mass.	1872	City.	Filter Basin.	Pumping.	Barr, Worthington.	Bituminous. Anthracite.	Pocahontas, Screenings.	$5 25	12.5	....
36	Ware, Mass.	1886	Town.	Wells.	Pumping.	Deane, Warren.	Bituminous.	....	5 00	..	$4 50
37	Wellesley, Mass.	1884	Town.	Wells.	Pumping.	Blake.	Bituminous.	Georges Cr., Cumberland.	4 63	9.0	3 50
38	Westerly, R. I.	1886	Town.	Driven Wells.	Pumping.	Worthington.	Bituminous.	Georges Cr.	4 84	..	6 00
39	Whitman, Mass.	1883	Town.	Brockton W. W.[1]	Pumping.	....	....	....	....	..	....
40	Winchendon, Mass.	1896	Town.	Well.	Pumping.	Blake.	Bituminous.	....	5 02	14.9	....
41	Woonsocket, R. I.	1884	City.	Crook Fall Brook.	Pumping.	Worthington, Deane, Builders I. Fdy.	Bituminous.	Pocahontas.	5 28	8.3	3 00
42	Worcester, Mass.	1845	City.	Reservoirs.	Gravity.	....	....	....	....	..	....
43	Yonkers, N. Y.	1876	City.	Brooks, Rivers, and Wells.	Pumping.	Wright, Worthington, Wood.	Bituminous.	Georges Cr.	4 10	10.8	12 00

[1] See Brockton.

1906. — TABLE 1, *Concluded.* — PUMPING STATISTICS.

Number.	3. Coal consumed for the year. (Lbs.)	4. Lbs. of wood ÷ 3 = equivalent coal.	4a. Amount of other fuel used.	5. Total equivalent coal consumed for the year. (Lbs.) (3) + (4).	6. Total pumpage for the year in gallons.	7. Average static head against which pumps work. (Feet.)	8. Averaged dynamic head against which pumps work. (Feet.)	9. Number of gallons pumped per lb. of equivalent coal.	10. Duty in foot-pounds per 100 pounds of coal. No deductions.	11. Cost per million gallons pumped into reservoir, figured on pumping station expenses.	12. Cost per million gallons raised 1 foot high, figured on pumping station expenses.
2	609 321	.....	....	....	223 793 920	...	188	367	72 955 200	......	......
							225				
4	1 040 557	.....	....	....	519 152 436[1]	126	146	496	60 789 667	$17 56	$0 12
5	308 311	.....	....	....	30 763 788[1]	290	318	100	26 419 693	65 84	0 21
6	1 772 279	.....	....	1 772 279	674 914 949[1]	202	288	381	91 469 329	11 64	0 04
7	2 864 600	.....	....	....	368 257 775[1]	289	316	129	33 237 044	23 02	0 07
8	4 316 255	500	....	4 316 755	3 386 180 600[1]	158	194	784	127 205 058	5 86	0 03
10	46 722 200[a]	.....	....	46 722 200[a]	21 552 886 258[1a]	171[a]	202[a]	461[a]	77 870 010[a]	4 21	0 02
11	2 139T	.....	....	....	1 634 300 539	...	185	341	....	10 52	......
13	893 659	.....	....	893 659	454 843 889[1]	117	140	509	59 427 110	12 24	0 09
14	11 994 858	.....	....	....	3 803 869 700[1]	200	235	321	65 132 042	5 33	0 02
15	1 955 678	.....	....	1 955 678	1 060 562 257[2]	190	203	730	91 812 308	12 01	0 06
								242			
17	7 904 865	2 400	....	7 907 265	1 855 043 406	156	164	235	62 941 506	20 60	0 13
19	1 835 100	.....	....	....	522 648 000[1]	201	231	...	....	......	......
20	622 900	.....	....	....	202 340 250[2]	172	174	318	47 138 879	12 99	0 07
*21*a*	3 014 777	.....	....	....	1 905 110 000[2]	...	121	632	65 670 000	6 64	0 06
b	518 933	.....	....	....	514 220 000[2]	...	128	991	114 550 000	3 50	0 03
c	8 518 537	.....	....	....	10 310 810 000[2]	...	132	1 210	136 740 000	2 91	0 02
d	7 955 358	.....	....	....	18 938 590 000[2]	...	51	2 381	104 520 000	1 69	0 03
e	2 533 049	.....	....	....	3 031 770 000[2]	...	128	1 197	131 600 000	4 03	0 03
22	638 510	.....	....	638 510	112 318 000[1]	182	204	176	29 928 012	......	......
23	9 811 025	.....	....	....	6 426 708 815	218	237	...	71 300 000 to 89 400 000	......	......
24	2 879 165	.....	....	2 879 165	2 493 186 540[2]	168	185	865	133 309 911	6 31	0 03
26	2 092 000	4 000	....	2 096 000	811 927 159[1]	235	262	387	84 643 400	11 65	0 04
27	555 900	.....	....	555 900	71 800 000[2]	80	84	111	9 050 000	34 68	0 40
28	442 140	.....	....	....	214 305 800	65	83	475	32 000 000	16 46	0 20
29	5 346 050	333	....	5 346 383	5 169 354 626[2]	171	180	967	144 947 660		
	682 800	.....	....	682 800	368 533 660[2]	170	174	540	78 545 307	L. S.	L. S.
	120 600	.....	....	120 600	81 354 806[2]	172	181	675	101 673 593	5 40	0 03
	1 524 518	911	....	1 525 429	614 370 545[2]	121	131	403	43 911 603	H. S.	H. S.
	26 766	70	....	26 836	10 665 717[2]	120	127	397	42 112 692	15 70	0 11

30	463 076	.....	....	....	53 551 083[2]	219	240	116	23 125 329	$47 26	$0 20
31	5 411 600	1 800	0	5 413 400	2 135 257 590[1]	213	292	394	96 089 905	6 12	0 02
34	489 900	.....	....	....	624 296 554	...	...	...	....	11 60	......
	1 377 300		.		698 149 375						
35	1 348 870	.....	....	....	705 360 048[1]	164	180	530	90 140 773	10 25	0 06
36	650 314	700	....	651 014	128 538 540[1]	221	244	197	40 178 980	28 50	0 12
37	616 472	300	....	616 772	99 481 861	260	280	161	37 646 000	29 63	1 05
38	1 504 600	500	0	1 505 100	264 982 500[2]	195	210	176	30 834 200	23 33	0 11
40	318 992	.....	....	....	40 305 620	246	289	148	36 349 966	28 33	0 10
41	1 472 850	607	....	1 473 457	446 894 141[2]	238	239	303	60 477 615	15 43	0 06
43	8 700 009	.....	....	8 700 009	2 543 288 786[1]	185	210	358	66 254 081	10 61	0 05
							222	264	46 562 747		

[1] Without allowance for slip.
[2] With allowance for slip.
a. Kirtland Street Station.

* 21*a*. C. H. H. S. Station, engines 1 and 2.
b. C. H. H. S. Station, engine 3.
c. C. H. H. S. Station, engine 4.
d. C. H. L. S. Station, engines 5, 6, and 7.
e. Spot Pond Station, engine 9.

1906. — TABLE 2. — FINANCIAL STATISTICS.

Number.	Name of city or town.	Receipts. Balance brought forward. a From ordinary receipts.	Receipts. Balance brought forward. b From extraordinary receipts.	Receipts. Water rates. A Fixture rates.	Receipts. Water rates. B Meter rates.	Receipts. Water rates. C Total from consumers.	Receipts. Municipal departments. D For hydrants.	Receipts. Municipal departments. E For fountains.
1	Arlington, Mass.	$9 672 88	....	$24 538 38	$14 438 01	$38 976 39	....	......
2	Attleboro, Mass.	....	$35 945 20	....	....	35 373 28	....	......
3	Belmont, Mass.	92 36	247 12	....	14 824 29	....	....	......
4	Beverly, Mass.	353 23	....	39 284 29	15 922 58	55 206 87	....	......
5	Billerica, Mass.	....	....	1 100 20	2 692 94	3 793 14	$2 300 00	......
6	Brockton, Mass.	....	21 742 44	3 149 17	97 965 34	101 114 51	....	......
7	Burlington, Vt.	45 111 42	947 41	6 641 81	38 920 17	45 561 98	620 00	$617 69
8	Cambridge, Mass.	....	....	....	....	357 280 19	....	......
9	Chelsea, Mass.	....	....	83 390 24	47 215 17	130 605 41	....	......
11	Fall River, Mass.	33 424 25	....	2 419 69	186 749 92	....	....	......
12	Fitchburg, Mass.	....	....	15 326 12	57 685 39	....	....	......
13	Gloucester, Mass.	14 565 43		65 576 50	18 944 86	84 521 36	....	......
14	Harrisburg, Pa.	....	....	34 340 38	140 544 11	174 884 59	....	......
15	Haverhill, Mass.	36 685 84	....	79 131 64	28 305 31	107 436 95	....	......
16	Holyoke, Mass.	3 865 25	....	86 522 97	31 000 29	117 523 26	....	......
17	Lowell, Mass.	31 791 82	....	28 816 73	150 373 42	179 190 15	....	......
18	Lynn, Mass.	....	1 988 22	113 684 29	130 702 29	244 386 58	....	......
19	Madison, Wis.	9 893 04	....	....	....	31 263 33	....	......

20	Marlboro, Mass.	$603 80	. . . .	$10 829 41	$26 553 15	$37 382 56	$6 700 00	. . . . . .
22	Middleboro, Mass.	1 007 71	. . . .	3 407 54	7 454 23	10 861 77	. . . .	. . . . . .
23	Minneapolis, Minn..	. . . .	. . . .	53 943 96	200 911 49	254 855 54	. . . .	. . . . . .
24	New Bedford, Mass.	37 316 64	$14 122 75	78 838 23	120 568 09	199 406 32	. . . .	. . . . . .
25	New London, Conn.	79 507 62	. . . .	. . . .	. . . .	66 389 86	12 840 00[1]	$300 00[1]
26	Newton, Mass.	. . . .	. . . .	2 157 00	120 325 00	122 482 00	. . . .	. . . . . .
27	Oberlin, Ohio	. . . .	. . . .	894 25	10 767 75	11 662 00	. . . .	. . . . . .
28	Plymouth, Mass.	. . . .	849 42	. . . .	. . . .	29 260 19	. . . .	. . . . . .
30	Reading, Mass.	28 19	. . . .	. . . .	11 047 52	11 047 52	4 950 00	300 00
31	Reading, Pa.	19 218 46	. . . .	157 368 79	53 430 52	210 799 31	. . . .	. . . . . .
32	Somerville, Mass.	. . . .	. . . .	133 886 92	92 533 42	226 420 34	. . . .	. . . . . .
33	Springfield, Mass.	19 249 10	. . . .	141 609 52	118 577 47	260 186 99	26 850 00[1]	670 00[1]
34	Taunton, Mass.	. . . .	3 353 53	. . . .	. . . .	71 236 11	. . . .	. . . . . .
35	Waltham, Mass.	5 651 09	60 760 07	59 180 57	15 490 75	74 671 32	. . . .	. . . . . .
36	Ware, Mass.	3 360 39	191 26	. . . .	9 173 86	10 503 87	. . . .	171 45
37	Wellesley, Mass.	4 768 82	513 90	240 00	15 832 69	16 072 69	3 500 00[2]	. . . . . .
38	Westerly, R. I.	12 061 66	. . . .	2 787 38	27 611 60	30 398 98	3 208 32	. . . . . .
39	Whitman, Mass.	17 80	. . . .	2 700 25	6 578 71	. . . .	2 920 00	. . . . . .
40	Winchendon, Mass.	917 55	. . . .	76 40	7 159 89	7 236 29	4 680 00	313 96
41	Woonsocket, R. I.	. . . .	. . . .	2 470 70	68 078 54	70 549 24	17 875 00	2 170 64
43	Yonkers, N. Y.	. . . .	45 899 60	. . . .	. . . .	160 198 15	30 990 00	. . . . . .

[1] Book account only.

[2] Includes fountains and street watering.

1906. — TABLE 2, *Continued.* — FINANCIAL STATISTICS.

Number	Receipts — *Continued.* Municipal departments — *Continued.* F For street watering.	G For public buildings.	H For miscellaneous uses.	I General appropriation.	J Total from municipal departments.	K From tax levy.	L From bond issue.	M From other sources.	N Total receipts.
1	....	....	....	$7 000 00	....	....	$835 41	....	....
2	....	....	....	1 000 00	....	....	....	$7 295 43	....
3	....	....	....	1 000 00	....	....	5 500 00	926 37	$22 343 02
5	....	....	....	937 09	....	....	....	57 04 149 32	....
6	$1 000 00	....	....	....	$1 000 00	....	45 000 00	60 329 59	229 186 54
7	1 687 12	$207 26	$45 111 42	....	....	....	....	947 41	....
8	....	....	....	....	....	....	....	5 961 77 3 627 24	366 869 20
9	....	....	....	....	....	$10 000 00	....	1 762 79	142 368 20
11	....	....	....	....	....	....	....	409 02 3 360 93	226 363 81
12	....	....	....	....	....	....	....	6 574 37	79 585 88
13	....	....	....	7 786 00	7 786 00	....	30 000 00	2 828 92	139 701 71
14	....	....	....	....	....	....	....	7 386 44	182 271 08
15	....	....	....	....	....	....	....	9 450 07	153 572 86
16	....	....	....	....	....	....	....	5 684 90	127 073 41
17	1 500 00	4 650 40	....	....	6 150 40	17 800 00	27 000 00	26 115 39	288 047 76
18	....	....	....	....	....	....	....	16 009 61	262 384 41
19	....	....	....	....	....	10 000 00	....	4 705 42	55 861 79
20	....	227 27	5 40	....	6 992 67	....	....	2 623 76	47 602 69

22	....	....	....	....	$1 500 00	....	....	$1 360 93	$14 730 41
23	....	....	....	....	....	$78 163 53	....	?	360 224 92
24	....	....	....	....	....	....	....	....	250 845 71
25	$1 500 00[1]	$1 500 00[1]	....	....	16 140 00[1]	....	....	....	163 144 99
26	3 000 00	2 681 00	....	....	5 681 00	....	$5 028 47	9 286 00 36 995 51	....
27	....	.........,	$456 88	....	456 88	3 076 95	....	358 10	15 553 93
28	....	....	....	....	....	....	....	3 563 29	....
30	500 00	....	....	....	5 750 00	....	....	843 01	17 668 72
31	....	....	....	....	0	....	....	14 571 24	244 589 01
32	....	....	....	....	....	....	....	7 880 11	234 300 45
33	6 627 45[1]	13 509 59[1]	4 503 65[1]	....	52 160 69[1]	....	....	27 442 55	359 039 33
34	....	808 50	....	....	....	10 000 00	....	3 619 00 1 250 51	....
35	....	....	1 820 60	....	1 820 60	....	40 000 00	3 608 30	186 511 38
36	....	37 00	365 29	....	573 74	2 700 00	....	229 25	....
37	....	263 34	....	....	3 763 34	....	5 066 67	1 586 30 416 48	32 188 20
38	....	....	....	....	3 208 32	....	....	2 896 38	48 565 34
39	110 22	....	....	$2 500 00	....	800 00	....	3 269 31	18 896 28
40	203 10	....	....	....	5 197 60	8 000 00	....	40 98	21 391 88
41	2 079 36	1 537 58	812 07	39 000 00	63 474 66	....	....	3 719 21	137 743 11
43	....	....	....	....	....	....	180 718 50	6 883 89	....

[1] Book account only.

1906.—TABLE 2, *Continued.*—FINANCIAL STATISTICS.

Number.	Maintenance Expenditures.			DD	EE	FF	Construction Expenditures.				
	AA	BB	CC				GG	HH	II	JJ	KK
	Operation.	Special.	Total maintenance.	Interest on bonds.	Payment of bonds.	Sinking fund.	Extension of mains.	Extension of services.	Extension of meters.	Special.	Total constr'tion.
1	$4 226 57	$13 663 78[1]	......	$12 960 00	......	$13 000 00	$835 41	$1 016 88	$2 887 66	......	......
2	....	....	$11 578 28	18 295 00	......	6 500 00	......	.....	.....	......	$33 260 62
3	2 134 87	5 668 67[1]	......	1 370 00	$3 250 00	520 00	2 565 11	1 003 37	941 66	$1 182 57	5 692 71
4	20 430 89	....	20 430 89	....	......	....	7 360 02	3 076 31	1 022 05	724 81	12 183 19
5	....	....	4 011 67	3 600 00	......	....	......	106 85	32 05	73 33	212 23
6	38 115 37	....	38 115 37	56 547 50	50 000 00	7 866 14	44 483 18	7 019 62	5 659 90	2 641 56	59 804 26
7	22 664 36	....	......	8 720 00	60 000 00	14 674 47	279 08	674 93	1 083 56	......	1 370 52
8	....	....	68 851 32	143 827 75	12 500 00	123 247 50	......	.....	394 77	......	318 460 76
9	12 387 74	57 687 81[1]	70 075 55	12 000 00	......	5 410 00	......	.....	3 636 74	......	8 655 14
11	....	....	47 595 87	67 910 00	......	....	17 642 99	.....	.....	23 781 19	....
13	23 007 55	....	23 007 55	41 600 00	45 000 00	....	3 835 66	5 923 51	.....	8 838 00 4 215 61	22 812 78
14	61 474 84	14 405 61	95 880 45	34 552 00	......	40 632 63	......	.....	.....	......	....
15	25 136 77	....	25 136 77	39 240 00	5 000 00	18 000 00	5 913 76	5 460 68	682 08	14 571 01	26 627 53
16	42 969 94	4 991 34	7 961 28	13 750 00	......	32 020 24	9 532 96	.....	2 246 40	16 151 00	27 930 36
17	109 294 73	....	109 294 73	45 668 00	16 600 00	17 800 00	34 432 72	8 443 95	.....	......	42 876 67
18	....	....	117 389 78	68 740 00	......	64 000 00	......	.....	.....	......	4 972 30
19	....	....	20 309 79	....	......	5 000 00(?)	......	.....	.....	......	23 786 99
20	9 368 25	....	9 368 25	20 760 00	......	....	......	.....	.....	......	2 682 96

22	$6 643 49	....	$6 643 49	$1 700 00	.....	$2 500 00	$3 104 26	$473 65	$190 80	......	$3 768 71
23	....	....	138 729 86	......	.....	....	......	.....	.....	......	166 992 27
24	40 562 72	....	40 562 72	68 880 00	$30 000 00	28 000 00	20 218 38	5 698 03	4 066 16	$9 536 44	39 519 01
25	10 276 37	....	10 276 37	21 915 35	.....	....	10 354 87	3 456 94	1 084 35	5 939 10	20 835 26
26	25 087 00	....	......	66 190 00	.....	....	17 750 60	11 610 61	3 677 80	8 984 97	42 023 98
27	4 976 52	$797 24	5 773 76	1 100 94	4 000 00	....	353 14	316 74	1 396 02	2 174 40	4 240 30
28	....	....	10 767 52	4 847 36	9 666 66	....	3 344 09	520 45	.....	9 630 12	13 494 66
30	6 268 83	....	6 268 83	8 105 00	.....	....	887 59	1 580 57	656 79	160 61	3 285 56
31	53 679 35	1 438 68	55 118 03	16 132 00	.....	51 500 00	16 068 03	1 675 83	3 327 59	43 450 87	84 522 32
32	27 946 76	97 160 08[1] 3 150 01	......	3 935 00	16 000 00	....	8 136 78	4 724 12	6 334 96	......	19 195 86
33	39 334 72	15 372 81	54 707 53	21 875 00	.....	....	24 054 14	.....	.....	755 02 61 857 87	85 156 99
34	30 734 89	....	......	34 195 00	.....	....	5 456 31	3 006 93	1 702 83	3 400 00	13 566 07
35	38 043 37	5 000 00	43 043 37	18 910 00	.....	14 000 00	3 464 84	4 875 60	160 00	29 771 80	38 272 24
36	7 436 71	....	......	1 065 00	2 700 00	....	......	.....	.....	......	1 878 83
37	7 156 00	....	......	11 320 00	.....	....	6 158 83	946 04	.....	......	....
38	10 015 42	....	10 015 42	13 361 70	.....	7 500 00	1 825 25	1 971 88	1 056 01	550 00	5 403 14
39	2 213 54	4 181 80[2]	6 395 34	4 800 00	.....	2 007 55 2 500 00	......	.....	.....	......	3 157 52
40	3 792 94	....	......	3 400 00	3 000 00	....	2 495 90	473 60	409 42	7 104 65	10 483 57
41	16 782 30	....	......	......	.....	....	......	.....	.....	......	24 917 21
43	....	....	87 924 07	86 783 33	.....	27 000 00	......	.....	.....	......	105 560 68

[1] Metropolitan water-works assessment.

[2] Paid city of Brockton for water and pumping.

1906. — TABLE 2, *Concluded.* — FINANCIAL STATISTICS.

Number.	LL Unclassified expenses.	MM Balance. *aa* Ordinary.	 *bb* Extraordinary.	N Total,	Disposition of balance.	O Net cost of works to date.	P Bonded debt at date.	Q Value of sinking fund.	R Average rate of interest. Per cent.
1	....	$9 283 25	....	....	....	$511 771 00	$326 000 00	....	4
2	....	....	$9 980 01	....	....	629 781 51	487 000 00	$40 526 70	.....
3	....	2 031 57	1 428 08	$22 343 02	....	....	38 250 00	5 820 02	4
4	$38 720 72	....	....	71 334 80	....	507 737 82	....	....	.....
5	....	—524 40	—62 91	....	....	92 490 23	....	....	.....
6	4 567 50	....	12 285 77	229 186 54	Forward.	1 713 251 95	1 485 000 00	523 065 53	3.6
7	....	....	....	....	....	491 446 59	188 000 00	14 674 47	4
8	4 710 37	....	....	....	....	6 342 200 46	3 383 600 00	1 509 749 85	3½–4
9	639 20	....	6 363 26	....	City Treasury.	507 580 57	300 000 00	110 824 00	4
11	....	69 433 76	....	226 363 81	....	2 076 499 40	1 550 000 00	530 768 51	3.99
12	45 212 66	34 373 22	....	79 585 88	City Treasury.	446 043 90	532 000 00	85 956 10	.....
13	6 683 39	482 99	115 00	139 701 71	....	1 386 358 50	1 143 000 00	....	3½ and 4
14	3 713 00	27 493 00	....	182 271 08	General Fund.	1 250 000 00	921 600 00	265 560 00	3½
15	26 464 77[1]	39 568 56	....	153 572 86	....	1 432 807 88	976 000 00	295 057 54	4
16	2 822 31	2 589 22	....	....	....	1 296 773 85	350 000 00	86 687 42	.....
17	13 355 81	25 101 61	17 350 94	288 047 76	Forward.	3 054 082 82	1 085 400 00	473 908 75	4
18	5 945 47	....	1 336 86	262 384 41	Const.	2 966 713 22	1 788 500 00	453 262 36	3¾
19	....	6 765 01	....	55 861 79	....	477 011 46	32 500 00	....	3¾ and 4

20	....	$14 791 48	....	$47 602 69	....	$592 170 84	$519 000 00	$233 149 45	4
22	....	118 21	....	14 730 41	....	121 962 80	39 000 00	13 068 11	4
23	....	....	....	....	....	....	1 930 000 00	....	.....
24	....	43 883 98	....	250 845 71	Forward.	3 332 753 27	1 578 000 00	367 538 48	4.28
25	$30 000 00[2]	80 118 01	....	163 144 99	....	1 019 340 86	601 000 00	....	3.6
26	....	46 172 00	....	....	....	2 232 446 00	1 387 000 00	494 911 00	4
27	146 67	292 26	....	15 553 93	....	118 277 77	43 000 00	918 12	3.5
28	....	....	—$5 103 30	....	....	379 758 21	119 999 82	....	3½ to 4
29	....	....	....	....	....	7 228 867 84	433 000 00	382 080 02	3⅓
30	....	9 33	....	17 668 72	Forward.	....	201 000 00	0	4
31	5 000 00[3]	32 316 66	....	244 589 01	Forward.	2 908 028 24	400 000 00	94 844 49	4
32	5 10	66 907 64	....	234 300 45	City Treasury.	874 698 99	86 000 00	....	4
33	52 022 52[2] 22 201 92	100 875 96 22 199 41[4]	....	359 039 33	Sinking Fund.	2 399 480 66	555 000 00	151 255 09	3.81
34	....	7 556 73	3 406 46	....	Sinking Fund.	1 347 106 32	838 500 00	326 595 77	3½ and 4
35	....	1 138 34	71 147 43	186 511 38	....	671 852 57	543 000 00	258 390 93	3.90
36	....	4 365 54	112 43	....	....	143 643 86	27 900 00	....	3½ and 4
37	72 57 1 703 94[2]	4 768 82	62 00	32 188 20	....	348 245 26	287 000 00	145 805 85	4
38	....	12 285 08	....	48 565 34	Forward.	375 296 80	353 000 00	67 413 27	3¾
39	....	35 87	....	18 896 28	....	165 674 03	120 000 00	....	4
40	....	715 37	....	21 391 88	....	142 205 27	82 000 00	....	4
41	....	....	96 043 60	137 743 11	....	258 304 54	1 032 000 00	154 540 35	3.8
43	....	....	29 258 22	....	....	2 189 040 07	1 895 000 00	304 378 92	5.33

[1] Depreciation. [2] To city treasury. [3] To park department. [4] Inventory.

1906. — TABLE 3. — STATISTICS OF CONSUMPTION OF WATER.

Number	Name of city or town.	1	2	3	4	5	6	7	8	9	10	11	12
		Estimated population.			Total consumption for the year. (Gallons.)	Quantity used through meters. (Gallons.)	Percentage of consumption metered.	Average consumption. (Gallons per day.)				Cost of supplying water. Per million gals.	
		Total at date.	On line of pipe.	Supplied at date.				Total.	To each inhabitant.	To each consumer.	To each tap.	Figured on total maintenance. (Item CC.)	Figured on total maintenance + int'st on bonds.
1	Arlington, Mass.	10 000	9 800	9 700	292 197 000	69 301 230	24	800 541	80	83	426	...	....
2	Attleboro, Mass.	14 000	13 500	....	223 793 920	....	..	640 635	43	45	...	...	....
3	Belmont, Mass.	4 550	4 350	4 250	....	57 395 800	..	272 900	62	..	...	...	....
4	Beverly, Mass.	18 000	18 000	18 000	519 152 436	....	..	1 420 168	79	79	...	$39 35	....
5	Billerica, Mass.	2 850	1 900	1 600	30 763 788	....	..	84 284	..	53	...	105 11	$222 13
6	Brockton, Mass.	57 000[1]	55 000[1]	54 400[1]	718 339 756	513 537 935	71	1 957 095	34	36	287	53 06	131 78
7	Burlington, Vt.	20 500	20 100	20 000	368 257 775	203 556 600	55	1 008 925	49	50	247	61 54	85 22
8	Cambridge, Mass.	99 934	99 934	99 934	3 386 180 600	1 252 836 750	37	9 277 207	93	93	615	20 33	64 25
9	Chelsea, Mass.	38 000	38 000	38 000	1 348 310 000	305 451 457	22	3 694 000	98	98	567	51 91	60 88
10	Cleveland, Ohio	480 237	478 000	477 000	21 552 886 258	13 050 513 080	60	59 049 003	123	124	876	20 41	28 51
11	Fall River, Mass.	107 911	....	106 370	1 634 300 539	....	..	4 477 536	41	42	...	...	....
12	Fitchburg, Mass.	33 300	....	31 000	1 062 000 000[2]	....	..	2 900 000[2]	..	93[2]	...	...	....
13	Gloucester, Mass.	26 011	26 000	20 000	454 843 889	86 036 444	20	1 246 140	48	62	314	50 58	142 04
14	Harrisburg, Pa.	68 000	67 000	70 000	3 803 869 200	2 504 711 500	66	10 421 560	149	149	751	19 56	29 03
15	Haverhill, Mass.	39 000	37 900	37 400	1 696 899 610[2]	....	..	4 651 779	119	123	732	14 22	37 94
16	Holyoke, Mass.	51 609	51 309	51 034	2 127 856 000	601 384 500	..	5 829 700	113	114	1 502	...	....
17	Lowell, Mass.	96 380	95 789	95 039	1 855 607 433	909 858 986	49	5 083 856	53	53	434	58 90	83 51
18	Lynn, Mass.	85 300	85 300	85 300	1 873 454 975	850 000 000	40	5 132 753	60	60	359	60 00	94 00
19	Madison, Wis.	25 000	....	23 766	....	191 394 096	..	....	57	..	362	...	....
20	Marlboro, Mass.	14 072	13 700	13 300	202 340 250	90 924 700	45	554 120	39	42	242	46 29	148 89
21	Met. W.W., Mass.	913 710	....	....	43 369 310 000	....	..	118 820 000	130	..	...	...	....
22	Middleboro, Mass., Fire Dist.,	4 700	4 400	4 100	112 318 000	50 721 789	45	307 720	73	79	339	...	....
23	Minneapolis, Minn.	275 000	220 000	209 000	6 426 708 815	2 511 393 000	..	17 607 421	64	..	...	...	....
24	New Bedford, Mass.	83 000	77 000	76 000	2 524 786 872	807 861 000	32	6 916 880	83	91	643	16 07	43 35
25	New London, Conn.	22 000	20 800	20 000	892 903 000	....	..	2 446 300	111	122	632	11 53	36 05
26	Newton, Mass.	38 000	37 600	37 500	811 365 333	514 000 000	63	2 222 919	59	59	290	...	....
27	Oberlin, Ohio	5 000	4 200	3 200	64 000 000	35 000 000	55	176 000	35	55	191	90 20	109 70
29	Providence, R. I.	219 800	....	219 800	5 491 558 313	....	60[2]	15 045 365	68	..	600	...	....
30	Reading, Mass.	5 725	5 625	5 125	53 551 083	....	..	146 715	26	29	118	117 93	270 40
31	Reading, Pa.	93 620	93 370	93 530	4 349 047 530	1 404 947 863	32	11 915 199	127	127	576	12 67	16 38
32	Somerville, Mass.	71 000	71 000	71 000	2 248 741 000	....	..	6 301 000	89	89	...	...	....

33	Springfield, Mass. . .	80 230	78 000	77 500	3 832 500 000[2]	778 281 426	20	10 500 000[2]	131	135	939	$14 27	$19 98
34	Taunton, Mass. . . .	30 967	28 500	28 000	698 149 375	287 297 278	41	1 912 738	62	68	386	44 02	93 00
35	Waltham, Mass. . .	27 350	27 200	26 950	705 360 048	76 121 745	11	1 929 726	71	71	533	53 95	94 96
36	Ware, Mass.	8 594	8 305	8 181	128 538 540	84 121 223	65	352 160	42	43	426	66 14	....
37	Wellesley, Mass. . .	6 315	6 070	5 030	99 481 861	61 061 440	61	272 553	43	54	268	...	....
38	Westerly, R. I. . . .	13 500	12 000	11 000	265 092 500	....	..	723 540	60	66	445	37 77	88 18
39	Whitman, Mass. . .	7 223	....	....	51 412 500	....	..	....	..	..	...	...	....
40	Winchendon, Mass. .	6 229	3 700	2 976	40 305 620	19 641 157	49	110 429	18	37	168	94 12	178 48
41	Woonsocket, R. I. .	36 957	37 457	36 957	446 420 731	326 048 066	72	1 223 070	33	33	419	37 59	....
42	Worcester, Mass. . .	138 891	136 582	136 582	3 363 756 000	2 082 903 499	61	9 217 384	66	69	373	26 95	70 09
43	Yonkers, N. Y. . . .	68 000	67 000	67 000	2 543 288 786	....	51	6 967 914	82	..	1 050	...	....

[1] Including Whitman.

[2] Estimated.

1906. — TABLE 4. — STATISTICS RELATING TO DISTRIBUTION SYSTEM. — MAIN PIPES.

Number.	Name of city or town.	1 Kind of pipe.	2 Sizes of pipes. (Inches.)	3 Length extended during the year. (Feet.)	4 Length discontinued during the year. (Feet.)	5 Total length in use. (Miles.)	6 Cost of repairs. (Per mile.)	7 Number of leaks. (Per mile.)	8 Length of pipe less than 4 ins. diam. (Miles.)	9 Hydrants. Number added.	10 Hydrants. Total in use.	11 Gates. Number added.	12 Gates. Total in use.	13 Gates. Number smaller than 4-inch.	14 Gates. Number of blow-off gates.	15 Range of pressure on mains. (Pounds.)
1	Arlington, Mass.	C. I., Cem. L.	4–12	757	....	35 7	$4 47	..	..	...	364	3	302	...	...	50 & 90
2	Attleboro, Mass.	C. I., W. I., Cem. L.	1–24	....	....	51 2	....	..	..	11	380	...	....	...	...	85–100
3	Belmont, Mass.	C. I.	2–12	2 247	0	21 0	....	0	0 5	3	163	7	264	25	12	15–100
4	Beverly, Mass.	C. I., Cem. L., Galv.	1–24	22 197	12 256	70 1	26 99	1 5	..	24	364	21	655	...	...	72
5	Billerica, Mass.	C. I.	6–12	....	....	9 7	....	0 1	..	...	103	...	84	...	4	54–120
6	Brockton, Mass.	C. I., Cem. L.	6–30	17 415	0	100 7	2 09	43	4 5	38	877	83	1 197	72	44	47–56
7	Burlington, Vt.	Cem. L., C. I., W.I.	4–30	240	0	40	....	..	4 8	...	218	...	679	70	14	70–85
8	Cambridge, Mass.	C. I.	2–40	7 443	1 357	128 1	....	18	2	15	1 046	19	....	0	...	55–60
9	Chelsea, Mass.	C. I.	2–16	2 542	....	39 6	....	..	0 1	10	319	6	441	0	41	50–75
10	Cleveland, Ohio	C. I.	3–48	160 982	18 353	677 0	11 05	0 46	2 6	324	7 966	685	14 941	...	...	20–100
11	Fall River, Mass.	C. I.	6–24	....	....	101 6	....	..	..	23	1 153	29	1 170	...	...	80
12	Fitchburg, Mass.	C. I., W.I., Cem. L.	2–30	2 214	....	72 6	....	..	..	13	593	10	660	...	...	75 & 165
13	Gloucester, Mass.	C. I., Cem. L.	1–20	5 130		63 1	27 31	0 07	19 6	3	303	12	483	152	27	15–75
14	Harrisburg, Pa.	C. I.	6–30	22 701	1 348	58	....	4	..	52	775	116	1 421	...	8	30–70
15	Haverhill, Mass.	C. I., Cem. L.	2–24	7 688	....	82	....	..	..	6	346	22	877	...	...	30–120
16	Holyoke, Mass.	W. I., C. I., Ld. L.	½–30	11 073	0	88 2	12 13	..	5 9	59	878	62	899	18	40	60–100
17	Lowell, Mass.	C. I.	4–30	27 778	....	140 5	....	..	2	42	1 271	82	1 441	30	34	17–72
18	Lynn, Mass.	Cem. L., C. I.	4–36	529	0	138	136 00	0 08	..	15	987	13	1 057	...	67	40–60
19	Madison, Wis.	C. I.	4–16	10 255	....	48 4	....	..	..	8	286	20	353	...	3	53–65
20	Marlboro, Mass.	C. I.	4–16	156	0	36 6	0 80	0 11	0 9	0	347	0	390	19	65	35–142
21	Met. W. W., Mass.	C. I., Cem. L.	6–60	....	....	83 8	....	..	..	...	....	1	361	...	...	......
	Met. Water Dist. (total in district supplied)	C. I., Cem. L., Kal.	4–60	14 16[1]	....	1535 1	....	..	..	198	13 690	...	....	...	...	......
22	Middleboro, Mass.	C. I.	4–12	2 134	12	17 9	....	..	..	3	127	8	193	...	6	40–70
23	Minneapolis, Minn.	C. I., W. I., Steel.	1¼–50	82 084	0	332 7	....	..	..	179	3 893	150	2 883	...	46	......
24	New Bedford, Mass.,	C. I.	4–36	13 448	2 545	106 3	7 95	0 10	0 9	34	1 105	34	1 272	114	105	25–95
25	New London, Conn.	Cem. L., C. I.	4–24	5 882	0	64	4 09	0 37	18 4	7	348	18	486	...	34	35–45
26	Newton, Mass.	C. I.	4–20	4 009	530	141 4	1 30	0 03	3 3	3	976	5	843	50	400	80–86
27	Oberlin, Ohio	C. I.	4–12	120	0	10 7	0	0	0 3	0	99	0	68	2	2	27–32
28	Plymouth, Mass.	Cem. L., W. I.	2–20	2 411	0	47 3	6 67	0 53	10 6	6	236	12	529	145	38	......
29	Providence, R. I.	C. I.	6–42	68 414	5 945	362 7	....	..	0	46	2 107	164	3 891	0	41	64–73
	H. P. Fire System	C. I.	12–24	0	....	5 6	....	..	..	0	92	...	31	...	4	114

30	Reading, Mass.	C. I.	6–12	675	0	29 5	$1 53	0	0	0	165	2	265	0	14	63–78
31	Reading, Pa.	C. I.	2–36	12 268	3 458	109 9	25 92	1 6	0 7	31	909	81	2 752	9	...	10–133
32	Somerville, Mass.	C. I.	4–20	5 369	....	91 3	0 86	0 09	..	17	1 067	18	1 376		136	35–100
33	Springfield, Mass.	Cem. L., W. I., C. I.	1–36	20 687	9 252	156 8	3 37	0 14	7 0	39	1 174	137	2 377	469	90	90–120 H. S 30–35 L. S.
34	Taunton, Mass.	C. I.	4–20	1 493	0	82 1	....	0 15	1 6	8	877	7	623	12	60	35–120
35	Waltham, Mass.	C. I., Cem. L.	2–24	13 987	9 900	53 7	5 14	0 3	2 0	13	415	16	758	44	63	50–70
36	Ware, Mass.	C. I.	4–12	0	0	12 6	....	..	1	...	121	1	128	13	3	90–95
37	Wellesley, Mass.	C. I., Cem. L.	1½–12	5 018	0	33 2	0 60	0 6	0 6	5	314	5	249	4	4	35–125
38	Westerly, R. I.	C. I.	4–16	288	0	34 1	....	0 09	..	2	163	2	213	...	...	......
39	Whitman, Mass.	Cem. L., C. I.	1–16	......	....	22 0	....	..	..	...	169	...	117	...	...	......
40	Winchendon, Mass.	C. I., W. I.	2–14	6 682	0	20 7	....	..	2 4	4	149	6	200	36	19	40–151
41	Woonsocket, R. I.	C. I.	4–20	8 438	0	53 2	4 92	0 09	0	13	624	22	549	0	15	50–120
42	Worcester, Mass.		2–40	....	....	197 2	....	..	..	...	2 012	...	2 868	...	...	......
43	Yonkers, N. Y.	C. I.	3–30	30 215	486	103 9	....	..	0 8	78	1 111	47	732	3	24	45–130

[1] Miles.

1906.—TABLE 5.—STATISTICS RELATING TO DISTRIBUTION SYSTEM.—SERVICE PIPES.

Number.	Name of city or town.	16 Service Pipe. Kind.	17 Service Pipe. Sizes. (Inches.)	18 Service Pipe. Extended. (Feet.)	19 Service Pipe. Discontinued (Feet.)	20 Service Pipe. Total in use. (Miles.)	21 Service Taps. Number added.	22 Service Taps. Total in use.	23 Average length of services. (Ft.)	24 Average cost of services for the year.	25 Meters. Number added.	26 Meters. Now in use.	27 Percentage of services metered.	28 Percentage of receipts from metered water. (B) ÷ (C)	29 Motors & Elevators. Added.	30 Motors & Elevators. Total in use.
1	Arlington, Mass.	C. I., Galv. I., Cem. Lined.	⅝–6	....	...	...	58	1 877	...	$17 53	233	652	34	39	...	5
2	Attleboro, Mass.	....	..	....	...	...	...	......	...	....	105	1 875	...	..	...	2
3	Belmont, Mass.	Cem. Lined, Galv.	1–6	3 325	68	7 7	44	754	76	31 82	44	754	100	..	...	...
4	Beverly, Mass.	Galv., Lead Lined.	¾–4	....	...	...	145	3 845	...	....	16	139	...	..	...	...
5	Billerica, Mass.	W. I., Cem. Lined.	1–1½	333	...	3 8	5	278	...	....	3	164	59	71	...	...
6	Brockton, Mass.	W. I., Ld. Lnd., Cem. Lnd., C. I.	¾–8	17 245	688	47 7	353	6 820	46	15 30	359	6 210	91	97	1	13
									20	8 86						
7	Burlington, Vt.	Galv., C. I., Lead.	½–6	1 550	125	19 9	62	3 696	25	13 50	119	2 983	81	.85	2	41
8	Cambridge, Mass.	Galv., C.I., Tin Lnd., Lead Lnd.	¾–8	4 835	...	117	129	15 062	37	17 51	82	2 935	19	..	...	...
9	Chelsea, Mass.	Lead.	⅝–2	2 321	...	33 1	88	6 509	26	18 26	318	951	14	56	0	5
10	Cleveland, Ohio	Lead, Galv., C. I.	½–16	....	...	...	4 436	67 519	14	....	12 001	56 168	83	86	—6	131
11	Fall River, Mass.	Lead.	½–2	....	....	...	101	7 845	...	....	143	7 666	...	..	...	...
12	Fitchburg, Mass.	W. I., Cem. Lined, C. I.	¾–8	....	...	...	50	4 795	...	....	81	3 149	...	..	2	117
13	Gloucester, Mass.	Cem. Lined, Galv.	1–6	2 296	...	15 6	120	3 968	20 7	36 40	6	218	6	22	...	...
14	Harrisburg, Pa.	Lead, Galv.	½–6	....	...	...	420	13 879	...	....	992	7 648	73	80	...	27
15	Haverhill, Mass.	Lead, W. I.	½–2	3 920	...	44 3	98	5 796	40	16 00	41	753	12	26	1	20
16	Holyoke, Mass.	Cem. Lnd., Rub. Lnd., Enam., Ld. Lnd., Tin Lnd., Galv.	½–4	1 280	17	15	81	3 881	20	15 00	10	318	...	..	2	112
17	Lowell, Mass.	Lead, Ld. Lnd., Tin Lnd., W. I.	⅝–2	10 384	...	87 5	285	11 719	36	29 63	501	8 377	71	84	...	...
18	Lynn, Mass.	Cem. Lined, Lead Lined.	½–4	22 400	600	109	397	13 953	40	18 00	466	4 590	40	60	...	4
19	Madison, Wis.	Lead.	⅝–2	5 272	...	19 6	258	3 961	...	....	282	3 865	98	..	...	...
20	Marlboro, Mass.	Cem. Lnd., Ld. Lnd., Lead, Galv.	¾–2	366	0	9 4	21	2 290	18	11 52	58	34 01	59	71	...	19
21	Met. Water Dist.	....	..	....	...	...	3 264	151 058	...	....	4 257	22 233	...	..	...	...
22	Middleboro, Mass.	Cem. Lined, Lead.	½–4	1 303	56	10 3	27	908	58	....	26	439	47	69	0	7
23	Minneapolis, Minn.	Lead, Galv.	⅝–1	....	...	...	...	30 070	...	....	5 742	19 276	...	..	0	8
24	New Bedford, Mass.	Lead, C. I.	½–10	14 713	741	71 9	287	10 764	35	18 50	371	2 803	26	60	10	167
										5 37						
25	New London, Conn.	Cem. Lined, Galv., Lead.	½–4	2 856	133	12 2	157	3 873	18	11 73	27	416	10	..	0	6
26	Newton, Mass.	Galv., Tarred I., Lead.	¾–6	11 515	4 160	85 8	98	7 673	59	23 93	182	6 642	87	98	1	19
27	Oberlin, Ohio	Galv., Lead.	¾–4	....	0	...	34	922	14	8 50	82	672	85	92	0	0
28	Plymouth, Mass.	Lead, Cem. Lined.	½–4	535	...	6 7	77	2 278	7	6 60	....	....	...	..	0	1
29	Providence, R. I.	Lead, C. I.	½–10	....	...	...	652	25 094	...	....	694	21 852	87	..	4	188

30	Reading, Mass. . .	C. I., Lead, Cem. Lined.	$\frac{3}{4}$–6	4 423	87	17 1	41	1 246	108	$38 55	46	1 130	91	..	0	4
31	Reading, Pa. . . .	Lead, W. I., C. I., Lead Lined.	$\frac{1}{2}$–8	....	...	...	785	20 685[1]	...	....	401	1 893	9	25	58	71
32	Somerville, Mass. .	Lead, Ld. Lnd., Cem. Lnd., C. I.	$\frac{1}{2}$–6	8 520	...	74 1	210	11 489	...	21 13	738	2 829	25	41	0	9
33	Springfield, Mass. .	Lead, Cem. Lnd., Tarred, Galv., C. I.	$\frac{1}{2}$–8	....	...	...	229	11 175	...	....	556	4 850	45	46	11	308
34	Taunton, Mass. . .	Cem. Lined, Tin Lined.	$\frac{3}{4}$–4	3 405	...	48 2	82	4 983	...	....	70	2 293	46	68	0	19
35	Waltham, Mass. . .	W. I., C. I.	$\frac{3}{4}$–10	8 402	2 170	45 0	82	3 620	62	40 65	10	320	9	22	0	10
36	Ware, Mass. . . .	W. I., Cem. Lined.	1–2	629	15	10 2	10	827	62	....	15	834	94	..	0	10
37	Wellesley, Mass. . .	C. I., Cem. Lnd., W. I., Lead, Ld. Lined.	$\frac{1}{2}$–8	4 060	196	20 4	31	995	92	11 12	36	1 016	100	100	0	0
38	Westerly, R. I. . .	Lead, Iron.	$\frac{1}{2}$–4	3 481	0	...	47	1 624	11	10 05	48	1 374	85	91	0	9
39	Whitman, Mass. .	....	..	....	...	...	70	1 248	...	....	63	700	...	..	...	...
40	Winchendon, Mass.	W. I.	1–2	2 274	0	5 7	48	657	47	9 87	35	619	97	99	0	1
41	Woonsocket, R. I. .	Lead, C. I.	$\frac{5}{8}$–6	1 687	0	8 4	141	2 917	10	....	138	2 504	86	96	0	16
42	Worcester, Mass. .	....	..	....	...	...	...	......	...	....	....	14 466	...	..	...	...
43	Yonkers, N. Y. . .	Lead, C. I.	$\frac{3}{8}$–8	....	...	...	372	6 637	...	....	453	6 660	100	..	0	7

[1] Estimated.

COMPUTATION OF THE VALUES OF WATER POWERS, AND THE DAMAGES CAUSED BY THE DIVERSION OF WATER USED FOR POWER.

BY CHARLES T. MAIN, MECHANICAL ENGINEER, BOSTON, MASS.

[*Read September 12, 1907.*]

DEFINITION OF VALUE.

1. The following definition of market value was given to the witnesses who were to testify on values in a recent important lawsuit.

2. " 'Market value' means the fair value of the property, as between one who wants to purchase and one who wants to sell any article; not what could be obtained for it under peculiar circumstances, when a greater than its fair price could be obtained; not its speculative value; not a value obtained from the necessities of another. Nor, on the other hand, is it to be limited to that price which the property would bring when forced off at auction, under the hammer. It is what it would bring at a fair public sale, when one party wanted to sell and the other to buy."

DEFINITION OF DAMAGE.

3. The definition of the damage due to the diversion of water was stated as, "The difference in market value, before and after the diversion."

METHOD OF DETERMINING VALUE.

4. The value of an undeveloped water power depends:

First. Upon its location, the amount and uniformity of flow, head, conditions affecting the cost of construction and transmission, use of exhaust steam and need of water for other purposes than power.

Second. Upon what the power is to be used for, whether for electric lighting and railway work, through most of the hours in the day with a variable load, for some use requiring a fairly steady

load for twenty-four hours a day, or for running a textile mill or similar plant with a fairly steady load for about ten hours a day.

Third. Upon the market which can be served, whether it is secure and steady or must be built up and is somewhat unreliable.

5. The value of a privilege should be determined by comparison with the cost of producing power in such quantities and with such regularity as is required for the particular purpose for which it is to be used in a fairly economical manner at any place or places equally convenient for the transaction of the business under consideration. Sometimes the location is fixed, but oftentimes there can be a choice of locations.

6. In estimating the value of an undeveloped privilege, the steps followed are as follows:

(1) Determine the flow, including the effect of storage and pondage.
(2) Determine the net head.
(3) Determine the horse-power which can be economically developed and used each month in an average year.
(4) Determine the minimum flow and power, and from this the size of supplementary steam plant required if the power is to be developed above the minimum flow.
(5) Determine the shortage of water power during such months as there is a deficiency.
(6) Estimate the probable cost of development of the water power.
(7) Estimate the probable cost of the supplementary plant, using steam, gas, oil, or anything which is best for the location under consideration.
(8) Estimate the yearly cost of running the water power and supplementary plants, including the fixed charges on both, to produce a combined power suitable for the purpose for which the power is to be used.
(9) Estimate the cost of a steam or other kind of plant, necessary to produce the power required.
(10) Estimate the yearly cost of running this plant, including fixed charges, to produce the power required.
(11) Subtract the cost of producing the power by water power and the supplementary plant from the cost of producing

it by steam power, or some other method, alone. The difference, if positive, gives the apparent yearly saving by the use of water power. The apparent saving should be modified if necessary for location or any other thing affecting the value.

(12) Capitalize this difference at a rate which seems proper, and the result is the value of the privilege.

7. There seems to be a great difference of opinion as to the proper rate of capitalization, but in the purchase of water power privileges the buyer of his own free will assumes certain risks, as damages caused by freshets, changes of business, etc., which he will not assume for nothing. He is also basing his comparisons of cost of power upon the present cost of producing power, which cost may be reduced in the future. For these reasons, the yearly saving should be capitalized at a rate not less than 10 per cent.

8. Where a whole property is taken and the owner is free to move into an equal or more favorable location, the method and rate of capitalization given above should be used.

If the privilege is developed the total value includes the value of the plant.

9. The value of a plant will be its cost, less depreciation, up to the point where the cost of water power equals that of steam or some other power. Beyond this point, when water power costs more than steam power, the value of the improvements, although new, would not be represented by the cost but would be something less than the cost. It is the sum which could be paid for it new which would bring the total cost of water power including fixed charges down to the cost of steam power, less depreciation.

METHOD OF DETERMINING DAMAGES.

10. The damage has been defined as the difference in value of the entire property before and after diversion.

11. It is usually unnecessary to go through an elaborate estimate of the value of the whole property, before and after the diversion, for the reason that many of the items of value will remain constant. The decrease in value, if there be any, is due to the fact that the running expense is increased by the diversion, and if this increased cost of running be capitalized at the proper rate

the capitalized sum will represent the amount which the property is decreased in value, or the damage.

12. In estimating the damage to an undeveloped or abandoned power, the value before and after diversion should be estimated as described under the previous heading. The difference represents the damage.

13. If a privilege is developed and used, a valuable business carried on and a plant established which cannot be easily moved, the definition of damage still holds good, but in such a case it is customary to capitalize the yearly loss at a smaller rate than 10 per cent., as this damage is done against the owner's wishes, and as he should receive a sufficient sum from which, in his business or in some other way, he can obtain a sufficient income to make good his yearly loss. The writer has, unless otherwise instructed, capitalized the yearly loss at 5 per cent.

14. A privilege which produces a variable power and has no supplementary power is not damaged any more than if it were so supplemented, and it should be treated in the same way as though it were supplemented.

15. The writer has generally used the following method of determining the damage to an established property, due to the diversion of some of the water.

(1) Determine the flow, including the effect of storage and pondage, before and after the diversion.
(2) Determine the net head.
(3) Determine the horse-power which can be economically developed and used before and after diversion.
(4) The difference between the power used before and after diversion is the power diverted which causes damage.
(5) Estimate the additional yearly cost of running caused by the taking away of this power, of coal, attendance, and supplies.
(6) If any permanent power has been taken, that is, power which can be relied upon in the lowest flow of the stream, estimate the cost of a steam plant or portion of plant necessary to make good the amount taken in the dry month.

(7) Estimate the fixed charges on this cost of additional supplementary plant.

(8) Add the extra cost of running and additional fixed charges and the sum represents the extra yearly expense.

(9) This extra expense capitalized at a proper rate represents the damage.

16. If it is necessary for the mills to maintain a steam plant of sufficient size to run the whole mill under the conditions existing before the taking, it is clearly not necessary for the defendant to furnish or maintain any further addition to the plant, and the damages consist of the increased expense of running the plant, already installed, due to the diversion.

17. If the total power required to run the mill is so large that the steam plant must be run all of the time, then there is no extra expense for attendance or supplies due to the diversion.

18. If the total power required is such that wheel plant can run the whole work for a portion of the year alone, and for the remainder must be supplemented by steam power, the time during which the engine must run may be extended by reason of the diversion, and in such case there is an addition to the expense of running for labor and supplies for such extra time, which should be added to the extra cost of coal, and the total extra expense capitalized at a proper rate will represent the damage.

WATERSHED AND RUN-OFF.

19. Too much stress cannot be placed upon the importance of determining the flow of the stream under consideration. If careful gagings have been made extending over considerable time they are the most reliable information which can be had. If no gagings have been made, an examination of the watershed should be made to ascertain its character, all existing rainfall records in the vicinity should be collected, and an estimate made of the run-off. Assistance may be had by comparison of similar rivers, the run-off of which is known.

20. The amount of data on the flow of streams which is available is increasing each year, as careful records are being kept on many rivers by persons or corporations who are interested in these matters, and by the United States Geological Survey.

21. The amount and uniformity of the run-off are two items which enter very largely into the value. The uniformity of flow depends largely upon the storage capacity and location of reservoirs on the watershed. The areas and capacities of such reservoirs should be ascertained and the net amount which can be drawn from them.

22. In estimating the average flow-off the months should be averaged in order of their dryness instead of in calendar order. If the flow is averaged by calendar months a great many irregularities in the flow are smoothed out and some of the flow is averaged which could not be held and used. By averaging all the dry months, all the second driest, and so on, some of this evening up is eliminated, but it cannot be altogether avoided. The average flow averaged by months in the order of their dryness will be less uniform and nearer the truth than when arranged by calendar months.

23. The average year is the one used in estimating the available power or power diverted, but the effect during the year when the flow is less than the average must not be lost sight of.

FLOW USED DURING WORKING HOURS.

24. The flow at any given privilege is usually given in cubic feet per second for twenty-fours hours a day and seven days a week.

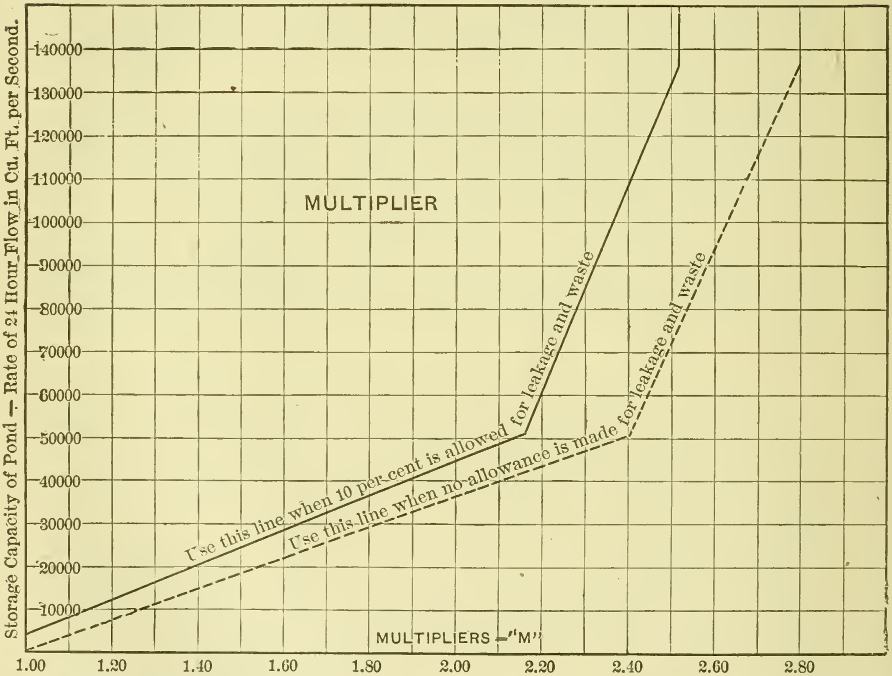
25. If the power is used twenty-four hours a day and there are no disturbing influences above to break up the uniformity of flow during the whole day, a small mill pond will answer. If, however, there are mills above using all the water in ten hours a day, a large pond would be necessary to store and use it all in twenty-four hours.

26. In a great majority of cases the water is used during the day for, say, ten hours a day and six days a week. If there is pondage enough so that it may be drawn down during the ten hours in the day enough to store the whole fourteen-hour night flow, and if no water were wasted, the ratio of the flow used in ten hours to the 24-hour rate would be 2.4; that is, 2.4 times the 24-hour rate of flow would be used during the ten working hours of the day. If the pond could be drawn down Saturday, so that the night and

Sunday flow could be stored, the ratio of 24-hour flow to that used in 10 hours a day and six days a week would be 2.8.

27. A certain amount of water is unavoidably wasted over the dam and by leakage through the various parts of the plant. This allowance of leakage and waste I usually place at 10 per cent. of the flow which could be theoretically stored and used. Using the above allowance for wastage, the maximum ratio of 24-hour flow to that which could be used in 10 hours, six days in a week, is $2.80 \times .90 = 2.52$.

28. When the pond cannot hold all of the flow during the time when the mill is not running, the ratio will be something less than 2.52, and when no portion can be stored the ratio is 1.



f = 24 Hour Rate of Flow in C.F.S.
S = Storage in Cu.Ft.
$M = \frac{9}{10}$ the ratio, which the amount of Water which can be used 10 hours per day, 6 days in the week bears to the total amount flowing during the week.
Main, C. T.

When "M" is less than 2.16

$$\text{"M"} = \tfrac{9}{10}\left(1 + \frac{S}{36000f}\right)$$

When "M" is greater than 2.16 but is less than 2.52.

$$\text{"M"} = \tfrac{9}{10}\left(2.4 + \frac{S - 50400f}{216000f}\right)$$

FIG. 1.

These ratios of amount of flow which can be used in 10 hours a day to the total flow have sometimes been called "multipliers." They are the figures by which the 24-hour rate of flow is multiplied to get the rate which can be used during the working hours.

29. The multipliers are computed for an isolated privilege by adding to the cubic feet naturally flowing in ten hours the cubic feet which can be stored each night, and to this adding one sixth the cubic feet which can be stored during the 24 hours of Sunday, and dividing this sum by the cubic feet naturally flowing in ten hours.

30. With a series of mills, some with small ponds might be enjoying the benefits of larger ones above, although they might have no rights in them. If the location were directly below the one with the larger pond, so that the lower privilege practically takes the water as it comes from the upper one, it will get the benefit of all or nearly all of the storage above. As the distance increases between the two privileges, the length of time required for the water to get to the lower one would increase and the benefit of the upper pondage would decrease. If it took one hour for the water to get down the multipliers would be 90 per cent. of those above; two hours, 80 per cent., and so on, plus any storage of water from the watershed below the upper privilege which can be stored in the lower pond.

31. Where there is a series of mills the multipliers can be computed in this way until a privilege is reached, where the multipliers due to its own storage are greater than those obtained for anything above. This power then becomes the governing one for those below it until another is reached having large enough storage to establish a new set.

32. The computation of these multipliers is tedious, and in order to facilitate the computation I have worked out the formula for them, and have prepared a diagram which reduces the labor to a comparatively small amount:

Let f = 24-hour rate of flow in cubic feet per second.

s = storage in cubic feet.

$M = \frac{9}{10}$ of the ratio which the amount of water which can be used in ten hours a day, six days a week, bears to the total amount flowing during the week:

36 000 = number of seconds in 10 hours.
50 400 = number of seconds in 14 hours, or one night.
216 000 = number of seconds in 60 hours, or one working week.
2.16 = 90 per cent. of 2.4 ratio of 10-hour flow to 24-hour flow.
2.52 = 90 per cent. of 2.8 ratio of 10-hour flow to 24-hour flow + $\frac{1}{6}$ of Sunday or 4-hour flow.

When M is less than 2.16,

$$M = \tfrac{9}{10}\left(1 + \frac{s}{36\,000\,f}\right).$$

When M is greater than 2.16 and less than 2.52,

$$M = \tfrac{9}{10}\left(2.4 + \frac{s - 50\,400\,f}{216\,000\,f}\right).$$

Fig. 1 shows the multipliers for various ratios of pondage to rate of 24-hour flow.

USE OF THE MULTIPLIERS.

33. The use of the multipliers is apparent when the problem is the determination of the amount of power which can be produced at a given place.

In estimating the damages caused by the diversion of a portion of the watershed, the power which can be produced before the diversion and the power which can be produced after diversion should also be estimated in the same manner, the difference between the two representing the amount of power diverted.

HEAD.

34. There may be several kinds of heads on the same development. There is the legal head, or the head to which the owner has a right to develop his power. This may or may not have been developed to its full extent. It may be that the expense involved would be too great to warrant further development. In some cases it might be economy to make the expenditure necessary to get the benefit of some unused portion of the head.

35. The gross head is the head actually used for producing power and getting the water to and away from the wheel.

36. The net effective head is the gross head minus the loss in head required to get the water to and away from the wheel.

This loss will vary with the length of the waterways leading to and away from the wheels, the velocity of the flowing water, and the construction of such waterways.

37. In several manufacturing cities where the water power is controlled by a company which is separate from the mill owners, there is an allowance of one foot made from the gross head before charging for the water as used on the wheels.

38. The head should be measured with the wheels running. The only portion of the head which produces power is the difference in level directly above and below the wheel when the wheel is running.

EFFICIENCY OF WHEELS.

39. Some tests of water wheels show a maximum efficiency of about 85 per cent. It is probable that over 80 per cent. is rarely realized in practice after wheels have been installed for a short time, and this is for three-quarters to full-gate opening. When the gate opening is less than about three-quarters, the efficiency begins to drop.

40. Fig. 2 shows an efficiency curve which has been published by one of the large wheel makers in their catalogue as the result of tests on one of their wheels. This is an excellent curve and represents a wheel of maximum efficiency which is not often found in practice.

41. After wheels have been run for some time the buckets and guides are not as smooth as when they are new, and the efficiency drops off. For these reasons I usually allow an average efficiency, for wheels running under ordinary conditions of age, repair, and variable gate opening, of about 75 per cent. Under exceptionally good conditions and where there are several wheels this could be increased.

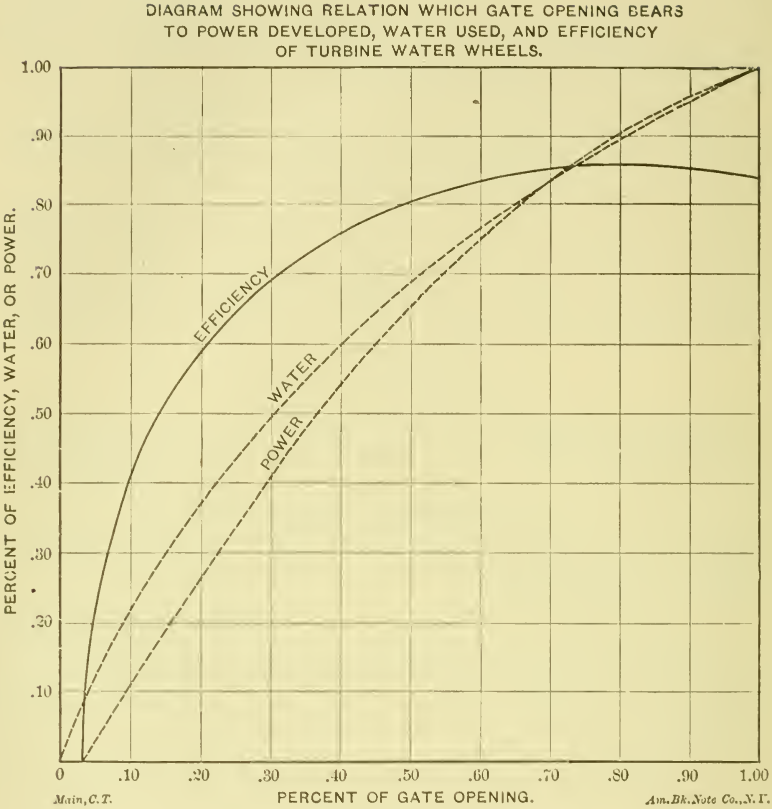


FIG. 2.

LIMIT OF LOW FLOW.

42. With vertical wheels and bevel gears, and belt drive to head lengths of shafting, the friction losses are probably from 5 to 10 per cent. of the total. With horizontal wheels the friction losses are probably from 2 to 5 per cent.

43. On Fig. 2 there is plotted in addition to the efficiency the percentage of water and of power produced for different gate openings. From this it will be seen that with a small flow the efficiency and the amount of power developed will be small, and unless the total drainage area is fairly large, or the low flow is sustained from storage, the power developed in dry months may

not be sufficient to run the wheel and overcome the frictional losses.

44. The flow required to produce 5 per cent. of the power is about 15 per cent. of the total water required to run the wheel full, and for 10 per cent. of power, 20 per cent. of water is required. With one wheel only there must, therefore, be a flow of say 10 to 20 per cent. of the total used by the wheel to produce any useful power. With several wheels properly arranged this could be reduced somewhat. At such times of low flow the water must either be stored and used for a short time in the day or it will produce no useful work.

EFFECT OF BACK WATER.

45. In a great many places there are periods during the year when the flow in the stream is so large that the water backs up below the wheel to a greater extent than the level of the water above the wheel can be raised, thus reducing the effective head and power. Sometimes the effect is so great as to prevent the use of the wheels.

EFFECT OF LOW FLOW AND BACK WATER.

46. The effect of low flow is to require an auxiliary power plant to make up the deficiency of water power, if it is necessary to run constantly, and if the flow drops so low as to produce no effective power, the auxiliary power plant must be of a capacity sufficient to run all of the work.

47. The effect of back water is to reduce the power produced by the water and to make it necessary to maintain a water power plant which has a surplus capacity in times of ordinary flow, or to maintain an auxiliary power plant and to run the same to make good the diminution of power if it is necessary to run full all the time. If the back water lasts for a long time and is so serious as to prevent any production of power from the wheels, the auxiliary plant must then be large enough to run the whole work.

LENGTH OF TIME DURING WHICH DIVERSION CAUSES DAMAGE.

48. In order to ascertain the difference in running expense due to diversion, it is necessary to know the average amount of power diverted and for how many months the diversion occurs.

This latter can usually be ascertained by knowing the capacity of the wheels in use, for in the majority of cases the wheel development will be an economical one.

49. It is sometimes the case, however, that larger wheels are installed than economy would warrant, by overestimating the flow, or some other cause. Wheels are sometimes installed to be used in times of back water, remaining idle at other times. Where the variation of the use of power during the day is large, as for electric light and railway purposes, wheels may be installed for the peak load where pondage will allow this method of running. If the length of time when the diversion causes damage is measured by the capacity of the existing wheels, it may appear to be for the entire twelve months of an average year. This cannot be true, for it would not pay to put in wheels to use all of the water in every month in the year. The diversion should be estimated for as many months as it would be economy to develop the power to use all the water under average conditions.

50. If the chance size of a wheel should be taken as measuring the length of time over which the damage continues, in a series of adjacent mills, some which had put in a portion of the wheel plant which could be used with economy would receive small damage, while a mill with a much larger wheel than would ordinarily be used would receive large damages thereby, when in point of fact the damage would be the same, other things being equal, and with a series of mills the damages would not be proportioned properly unless the wheels were installed in each on the same basis of economical development.

ECONOMICAL DEVELOPMENT OF WATER POWER.

51. In a large number of water power developments which I have examined, a very large percentage have been developed with wheel capacity sufficient to use all of the water from six to seven months in an average year, and during the remaining months water would go to waste. The economical development has been stated by some engineers to be nine months. No general statement is applicable to all conditions. It is a question of economics which requires solving for each particular case.

52. The factors which enter into the problem are on one side

the cost of the water power development and the fixed charges on the same, plus the cost of water if anything is paid for it, and on the other side the saving which can be effected by the use of such a plant.

53. The cost of the dam will be a constant for any size of wheel development, other things being equal. The head gates, canal, racks, feeders, wheels, wheel-pits, and tailraces must be increased in size and cost for the purpose of using a larger amount of water than the flow in the average month or sixth month of an average year, and the fixed charges for such increase in cost, plus the cost of water, represent the annual cost of the corresponding increase in water power.

54. The saving due to such increase in water power is represented by the saving in coal only on supplementary steam plant, necessarily run with such a varying water power, plus the cost of attendance and supplies on steam plant if it can be shut down entirely during the months of maximum power on the wheels. As the water power is increased in size to use water for a greater number of months, the cost of such increase for each additional month makes a saving for a less number of months, and there comes a time when the saving on steam power is less than the fixed charges on the additional cost of water power plant. Where these two items balance depends upon the following conditions:

(1) Cost of running the water power plant for each increment of power.
(2) Saving effected by the decreased use of steam power.

55. The variation in the cost of the water power plant per horse-power is very large. The principal causes for this are the variation in head and distance from the source of supply of the water to the point of discharge. The cost of construction will also vary with local conditions.

56. The saving effected would also vary largely, depending principally upon the number of hours run during the day, the cost of coal, and whether by increasing the size of water power plant the auxiliary power plant could be stopped during the months in which the water power was producing full load.

57. An example will suffice to make this clear. Supposing

the cost for each additional horse-power of water power plant required to use all the water for a longer period was $60 a horse-power. The fixed charges on this, including interest, will be not less than 8 per cent., or $4.80 per year. The cost of coal and attendance on a steam plant of say 500 horse-power, when running ten hours a day, with coal at $4 per ton, is about $13 per year per horse-power, or $1.08 per month. $4.80 ÷ $1.08 = 4.44 months. In other words, it would not pay to develop such a power to use all the water for more than about seven and one-half months.

58. If the engine or boilers cannot be shut down at all, a less saving could be made and the power could be economically developed for a less period than seven months.

59. The various conditions and lengths of time required to have the saving equal the fixed charges are shown in Fig. 3. This diagram is figured on coal at $4 per ton, and with a running time of ten hours a day, six days a week. Similar diagrams could be made for any other prices of coal and time of running.

60. To use the diagram, supposing the water power plant cost $50 per horse-power, and the size of steam plant is 200 horse-power. On the ordinates find $50 cost of water power plant. Run along horizontally until this line intersects the vertical line of 200 horse-power of steam plant, and these two lines will be found to intersect about on the curve marked three months.

If the water plant cost $70 and the steam plant were 350 horse-power, the time is five months during which water should waste.

TABLE SHOWING FLOW AND POWER.

61. The table on page 232 shows a convenient form for tabulating the flow and power. The first half is useful in estimating the value of a privilege, and the whole table for estimating damages when a portion of the flow is diverted.

62. The only thing needing explanation is the figure .0851 which appears in the headings of columns 6 and 12. This is the horse-power produced by one cubic foot of water per second on one foot head with an efficiency of 75 per cent. With 80 per cent. efficiency the figure is about .091.

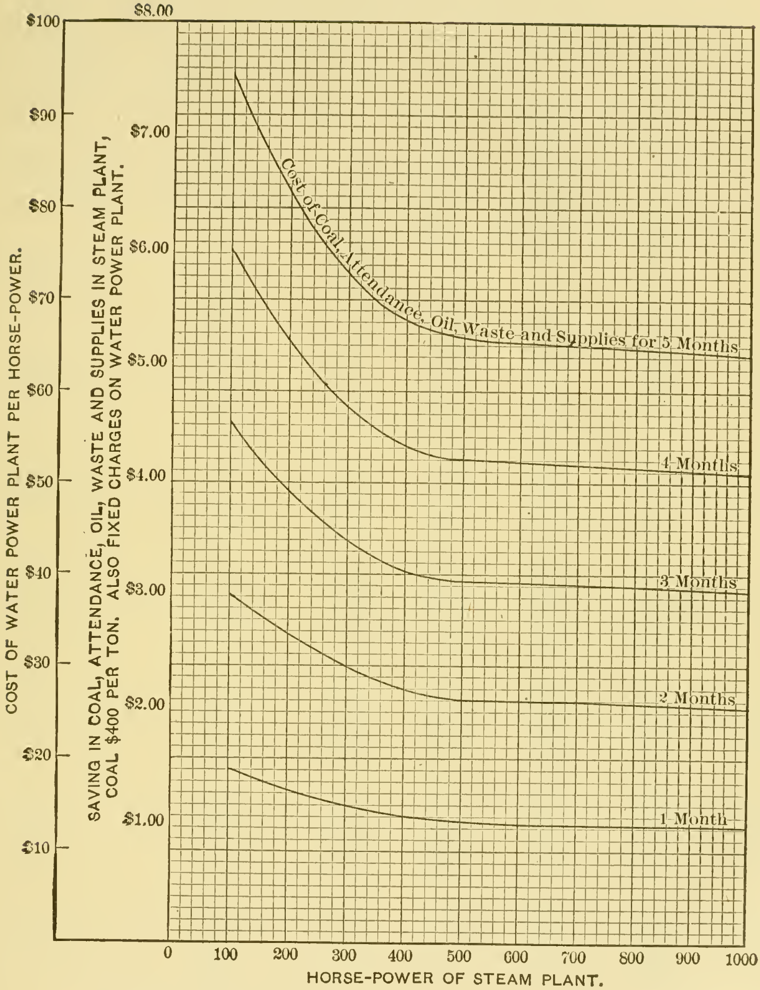


DIAGRAM SHOWING NUMBER OF MONTHS WHEN WATER SHOULD BE ALLOWED TO WASTE WITH DIFFERENT SIZES OF STEAM PLANTS AND DIFFERENT COSTS OF WATER POWER.

Main, C.T. *Am. Bk. Note Co., N.Y.*

FIG. 3.

APPROXIMATE COST OF WATER POWER DEVELOPMENT.

63. In connection with the preceding diagram is printed a table, page 231, showing approximately the cost per horse-power of water power plants, not including dam, canal, and buildings, for different heads, distances from feeder head to end of tailrace, and horse-power of development.

It is not expected that this table will cover all cases, but it will give approximate figures for ordinary conditions, and is useful in making rough preliminary estimates.

TABLE OF ESTIMATED COSTS PER HORSE-POWER OF WATER POWER PLANTS

Having Horizontal Turbines, Steel Penstocks, and Walled Tailraces —Dam and Buildings not Included.

	"L".	10-ft. fall.	15-ft. fall.	20-ft. fall.	30-ft. fall.	40-ft. fall.
1,000 H.-P	100 feet	$65.14	$40.92	$29.37	$19.40	$14.59
	200 "	71.91	45.48	32.84	21.70	16.38
	300 "	78.66	50.05	36.30	24.01	18.17
	400 "	85.43	54.62	39.77	26.32	19.95
	500 "	92.20	59.18	43.23	28.63	21.74
	600 "	98.96	63.75	46.69	30.94	23.53
900 H.-P............	100 "	65.35	41.00	29.56	19.56	14.79
	200 "	72.08	45.58	33.04	21.85	16.60
	300 "	78.80	50.16	36.53	24.14	18.41
	400 "	85.50	54.74	40.01	26.41	20.22
	500 "	92.24	59.32	43.49	28.70	22.02
	600 "	98.96	63.91	46.97	30.99	23.84
800 H.-P............	100 "	65.48	41.10	29.65	19.68	14.99
	200 "	72.22	45.68	33.12	21.98	16.78
	300 "	78.95	50.26	36.68	24.28	18.57
	400 "	85.70	54.84	40.04	26.56	20.35
	500 "	92.43	59.41	43.52	28.87	22.14
	600 "	99.15	64.00	46.98	31.17	23.93
700 H.-P............	100 "	65.72	41.19	29.87	19.90	15.12
	200 "	72.48	45.75	33.35	22.19	16.93
	300 "	79.23	50.30	36.82	24.49	18.73
	400 "	86.00	54.86	40.29	26.77	20.54
	500 "	92.74	59.42	43 77	29.07	22.34
	600 "	99.50	63.97	47.25	31.37	24.16
600 H.-P............	100 "	65.86	41.56	30.00	20.02	15.37
	200 "	72.64	46.14	33.49	22.34	17.20
	300 "	79.42	50.72	86.97	24.64	19.04
	400 "	86.20	55.30	40.45	26.95	20.87
	500 "	92.98	59.88	43.94	29.27	22.70
	600 "	99.76	64.47	47.42	31.57	24.54
500 H.-P............	100 "	66.00	41.70	30.24	20.24	15.52
	200 "	72.82	46.32	33.78	22.56	17.31
	300 "	79 64	50.94	37.28	24.86	19.10
	400 "	86.46	55.56	40.80	27.16	20.88
	500 "	93.28	60.16	44.34	29.48	22.66
	600 "	100.10	64.80	47.84	31.80	24.44
400 H.-P............	100 "	66.28	42.03	30.55	20.79	16.00
	200 "	73.16	46.65	34.05	23.10	17.82
	300 "	80.03	51.26	37.53	25.40	19.64
	400 "	86.90	55.88	41.03	27.73	21.45
	500 "	93.78	60.50	44.53	30.03	23.27
	600 "	100.65	65.13	48.03	32.35	25.08
300 H.-P............	100 "	66.87	42.67	31.09	21.49	16.50
	200 "	73.70	47.30	34.57	23.83	18.33
	300 "	80.54	51.94	38.07	26.18	20.16
	400 "	87.33	56.54	41.54	28.53	22.00
	500 "	94.17	61.18	45.04	30.88	23.83
	600 "	101.00	65.78	48.51	33.22	25.67
200 H.-P............	100 "	68.50	44.22	32.45	22.61	17.60
	200 "	75.35	48.84	35.97	24.97	19.47
	300 "	82.25	53.45	40.04	27.33	21.34
	400 "	89.10	58.10	43.56	29.70	23.21
	500 "	96.00	62.70	47.08	32.06	25.08
	600 "	102.85	67.35	50.60	34.43	26.95
100 H.-P............	100 "	71.39	46.64	34.76	24.75	19.80
	200 "	78.43	51.37	38.39	27.17	22.00
	300 "	85.47	56.10	42.02	29.59	24.20
	400 "	92.51	60.83	45.65	32.01	26.40
	500 "	99.55	65.56	49.28	34.43	28.60
	600 "	106.60	70.28	52.91	36.85	30.80

Note: "L"—Distance from Feeder Head to end of Tailrace. Cost of Canal, if any, not included.

TABLE .... NAME ....

	Flow and Power before Diversion.							Flow and Power after Diversion.						Power Diverted.
Col. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Months in the order of their dryness.	Natural flow in cu. ft. per sec. on one square mile.	Total flow cu. ft. per sec. = Col. 2 × square miles.	Multiplier or ratio of flow which can be used in 10 hours to 24-hour rate.	Total flow which can be used in 10 hours a day = Col. 3 × Col. 4.	H.-P. which can be used in 10 hours a day on one foot fall = Col. 5 × .0851.	Total H.-P. which can be used in 10 hours a day = Col. 6 × ft. head.	H.-P. which present wheels can use or which would ordinarily be developed.	Total flow cu. ft. per sec. = Col. 2 × square miles.	Multiplier or ratio of flow which can be used in 10 hours to 24-hour rate.	Total flow which can be used in 10 hours a day = Col. 9 × Col. 10.	H.-P. which can be used in 10 hours on one foot fall = Col. 11 × .0851.	Total H.-P. which can be used 10 hours a day = Col. 12 × ft. head.	H.-P. which present wheels can use or which would ordinarily be developed.	H.-P. diverted which causes damage = Col. 8 − Col. 14.
Dryest.....														
2d "														
3d "														
4th "														
5th "														
6th "														
7th "														
8th "														
9th "														
10th "														
11th "														
Wettest........														
Totals and Averages...														

Average H.-P. diverted .... for .... months in an average year ....

EXTRA LENGTH OF TIME WHICH STEAM PLANT MUST RUN ON ACCOUNT OF DIVERSION.

64. If the power of the stream before and after diversion, is worked out it will probably be found that the auxiliary power plant must be run for a longer time after the diversion.

65. This would be shown in full months in the tables showing the power before and after diversion, but it would not show fractions of a month.

66. The method of ascertaining the extra length of time is shown in Fig. 4. The ordinates show horse-power which the whole stream can produce and the abscissæ the number of working days. By plotting the horse-power which can be developed before and after diversion, and drawing diagonal lines from month to month, the extra number of days when the auxiliary plant must run is shown where the diagonal lines cross the horizontal line of wheel development.

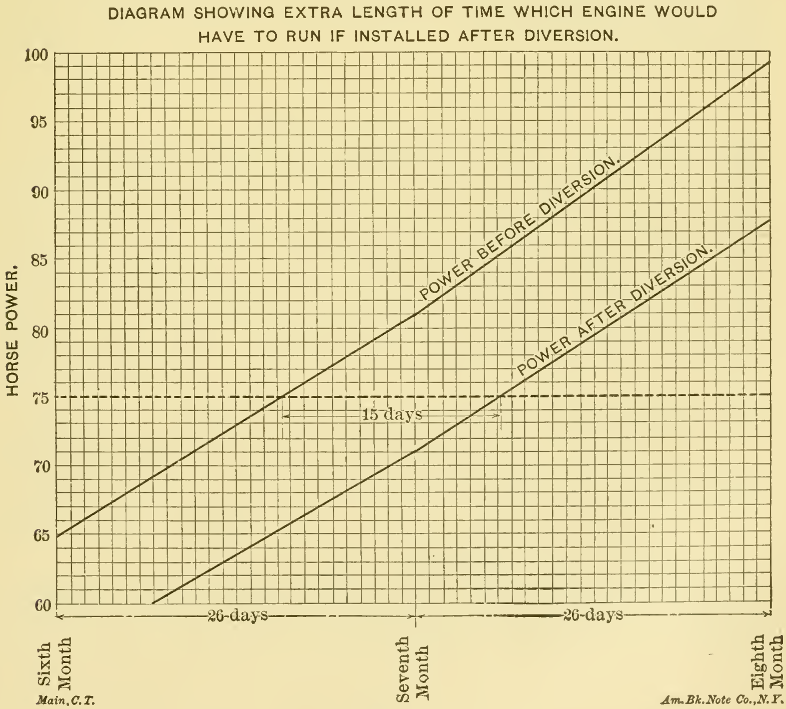


FIG. 4.

STEAM OR OTHER POWER PLANT TO BE USED IN MAKING GOOD THE POWER DIVERTED.

67. In order to determine the damage, it is necessary to estimate the cost of replacing the power taken away, not necessarily by the auxiliary plant already existing at the mill, for such a plant may be an extremely uneconomical one and the mill which had the poorest plant would get the most damages, but by a *fairly economical plant of the size and character such as the business under consideration would naturally use.* Unless this method is pursued with a series of mills, the one which had put itself into the best shape would receive a smaller amount of damage than its neighbor where things were in bad shape.

68. It is improbable that a concern would go on putting in each time it renews its plant an uneconomical plant, and it is highly probable that the low-grade engine will be improved in efficiency. As the damages are figured forever, it will add very little to the damages for the comparatively short time which the uneconomical plant will be obliged to run.

PRIVILEGES WITH NO AUXILIARY PLANT.

69. The basis on which the damages should be estimated in these cases where there is no auxiliary power plant is the same as for any other. The mere chance that an owner can manage in some way to run his business in accordance with the fluctuating flow of the stream does not entitle him to any greater damage than his neighbor who is fitted up to run continuously. A small amount of power diverted will not make the conditions enough worse in most cases to require the addition of a supplementary plant for that reason alone. An allowance, however, should be made in estimating the damages in such cases for such portion of a steam plant as would ordinarily be installed to produce a uniform power as is equal to the power diverted in the dry month, and the running expenses should be estimated on a plant of full size and not on a very small plant.

70. The proper method of ascertaining the damages to a plant of this sort is to find the difference in value before and after

diversion, and this is obtained by finding the cost of producing a uniform power before and after diversion.

ALLOWANCE FOR PERMANENT POWER DIVERTED.

71. If any power is diverted which can be depended upon all the time, an allowance should be made for this. If the diversion is comparatively small the fixed charges should be allowed on the cost of a portion of the large plant equivalent to the amount of power diverted. Thus, supposing 5 horse-power is diverted in the dry month, and the cost of the steam plant is $60 per horse-power: 5×$60 = $300. $300 @ 12% = $36. This capitalized at 5% = $720.

If this allowance is made the owner may increase the capacity of his plant by 5 horse-power when he renews it, and will have been recompensed for this expense.

If the interest charges are not included in the fixed charges, the cost of plant, $300, should be added to the capitalized sum.

If the diversion is a comparatively large amount, it may be necessary to remodel and increase the existing steam plant, or to put in a new one. Allowance should be made in the same way for this.

COST OF STEAM POWER.

72. The cost of steam power usually has an important bearing upon the settlement of damages. The accompanying Figs. 5, 6, and 7 have been prepared, which show the yearly cost of producing steam power under various conditions and costs of coal when running ten hours a day and six days a week with a fairly steady load. They are intended to show the expense of running under everyday conditions on such a plant as a prudent man would install and run with ordinary skill.

The cost of 24-hour power for 365 days a year is about 2.2 times the cost for 10-hour power for 308 days.

The cost of 24-hour variable load cannot be stated without knowing all the conditions.

COAL CONSUMPTION USED IN ESTIMATING DAMAGES.

73. The coal consumption used in estimating damages when the power diverted must be made good under a varying load contingent

upon the fluctuation of the water power should be somewhat larger than the coal consumption for a fairly steady load. I have usually added about 20 per cent. to the coal consumption required for a steady load. The fluctuation of the water power will usually

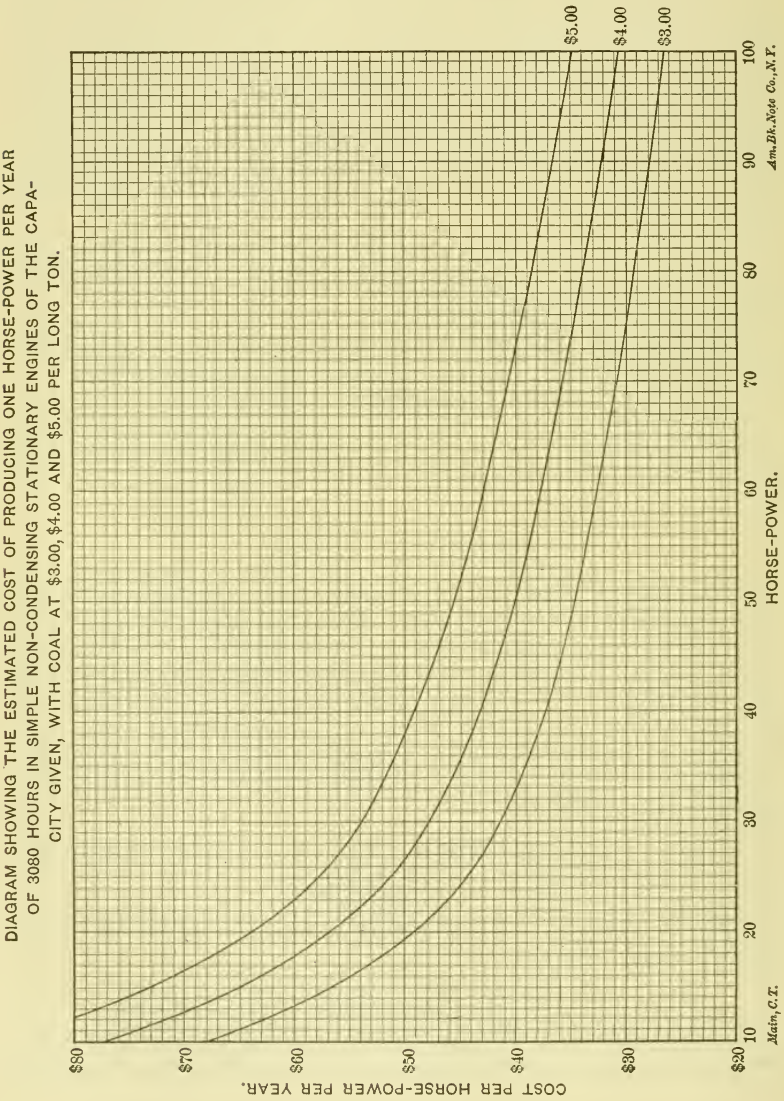


FIG. 5.

not be great for a single day, but the variation covers longer periods, as weeks or months.

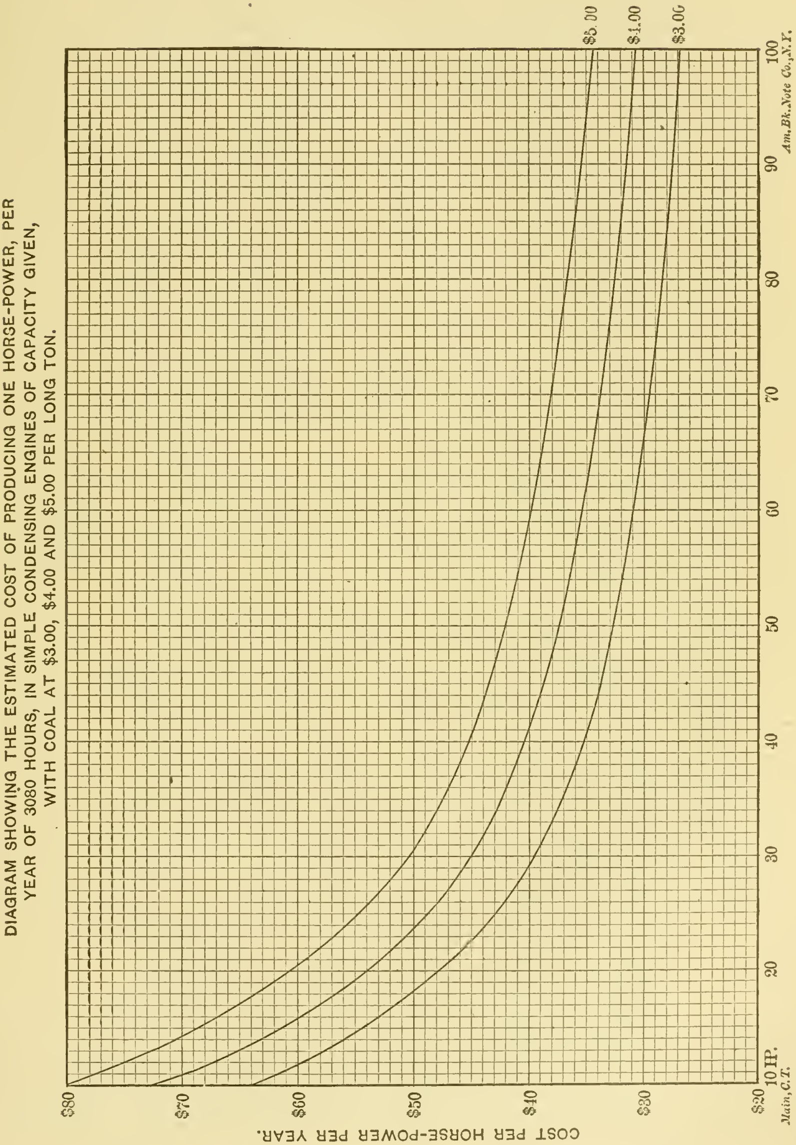


FIG. 6.

DIAGRAM SHOWING THE ESTIMATED COST OF PRODUCING ONE HORSE-POWER PER YEAR OF 3080 HOURS, IN COMPOUND CONDENSING ENGINES OF THE CAPACITY GIVEN, WITH COAL AT $3.00, $4.00, OR $5.00 PER LONG TON.

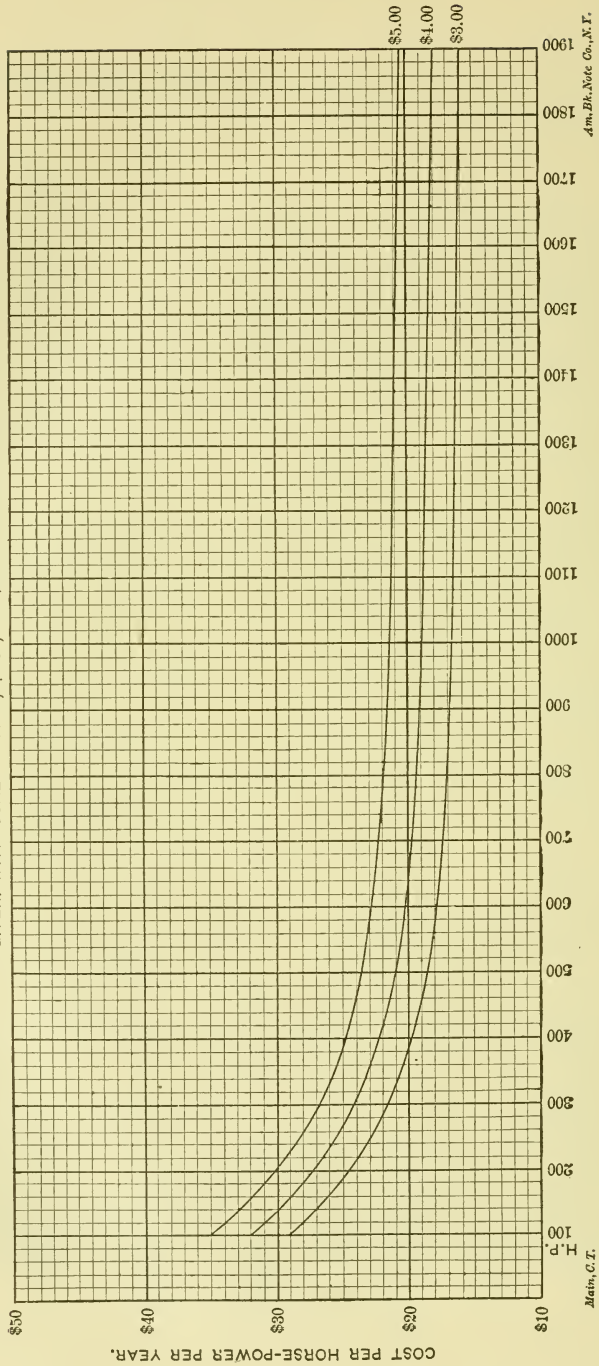


FIG. 7.

EFFECT OF USE OF STEAM FOR OTHER PURPOSES.

74. In many textile and other mills low-pressure steam and hot water can be used in the manufacturing processes, and for warming the buildings: The amount varies largely, in some cases being more than the equivalent amount of steam exhausted from an engine large enough to run the work, or to the amount of water required for condensing for an engine of the same size. Rarely in a textile mill would the amount fall below 20 per cent. of the total heat rejected by the engine. This has the effect of reducing the value of water power for such mills, and has the effect of reducing the damages as figured on straight power conditions.

75. It is never attempted, however, to estimate this effect in suits for damages. It should be considered in estimating values, and it has its effect upon the selling value of water powers, making them of less value for industries having use for low-pressure steam and warm water.

76. All of the varying conditions of different industries have an effect of producing a sort of average selling value for water powers, but each case requires examination and estimates of its own.

EFFECT OF ELECTRICAL TRANSMISSION.

77. The statement is frequently made that water powers have increased in value since it became possible to transmit power electrically.

78. To be correct the statement should be modified. Since the introduction of electrical transmission many water powers which were before unavailable and valueless have been developed and become of value, and many others will be in the future, but water powers which have been developed and the power used adjacent thereto have, as a rule, not increased in value.

DETERMINATION OF VALUE OF REMOTE POWERS.

79. All of the preceding described methods are applicable to the determination of the value of a remote water power which may be capable of development with electrical transmission to some market, but there must be added one or two steps in the process.

80. To the cost of the development must be added the cost of the electrical apparatus and pole line to a point where the power is to be used, and this is a large item of expense in long-distance transmission. Usually, also, there must be added to the cost of the physical part of the plant a considerable amount for right of way for pole line, legal expenses, and cost of financing the scheme.

81. To the running expenses must be added the fixed charges for the electrical apparatus and pole line, and the cost of running and maintaining the same.

82. A correction must also be made for the loss of power in transmission.

83. A comparison of the cost of producing and transmitting power can be made with the prices which can be obtained for this power to determine if the development has any value, and whether the development is warranted or not. The price which can be obtained for the power depends largely upon the cost of producing power by steam, or in some other way, at the point of delivery.

POWER USED FOR ELECTRIC LIGHTING AND RAILWAYS.

84. In the majority of developments for electrical transmission the power is used to a large extent for electric lighting and railways; sometimes, in addition, for manufacturing purposes, and occasionally for manufacturing only.

85. When used for lighting and railways the power is usually exceedingly variable, resulting in a low power factor. The conditions are so variable that it would be useless to try to show in this paper the probable cost of power produced by steam under such varying conditions. Each case must be worked out to meet the special conditions of the problem under consideration.

DAMAGES CAUSED BY THE DIVERSION OF WATER POWER.

BY CLEMENS HERSCHEL, CONSULTING ENGINEER,
NEW YORK CITY.

[*Presented September 12, 1907.*]

A full discussion of this subject necessarily treats of legal matters about as much as it does of hydraulic or other engineering. It must, indeed, be founded on a consideration of the fundamental rule of law, frequently quoted, that the measure of damage done a piece of real estate by the diversion from it of a certain quantity of water hitherto flowing through it is the difference between two market values of that piece of real estate, the one estimated or judged as of date before the taking of the water right; the other appraised as of date after that taking.

Two sums of money are to be attained or determined in the minds of the masters or other tribunal charged with the duty of awarding the damage done or suffered in such cases, and their difference is the sum of money to be awarded to the claimant. Nothing simpler, one is tempted to say at the beginning of such hearings; only a simple sum in subtraction to be performed. And yet no class of cases has probably given rise to greater wrangling or presented at times a more lamentable spectacle of the incompetency of man to undertake the perfect administration of that one of the highest of divine attributes — the administration of justice.

There is, we will assume, no dispute as to the work to be done so far described, no dispute as to the rule of law to be applied as it has been above stated. Let us, therefore, briefly comment on the words and language of the statement made and recall some elementary principles and definitions not always present in the minds of laymen to the law, but to which experts in engineering must give due heed if they would aid in the administration of justice and be experts in fact as well as in name.

Our comments may follow the order of words as above written in stating the rule of law to be followed, and we thus come upon the words " real estate."

(1) These cases deal with damage to a piece of real estate.

They do not ordinarily deal, certainly not as far as the engineering expert is concerned, with damage done to the business carried on upon this real estate, nor with that done any particular individual. It is the real estate that is damaged, and it is this injury which is to be measured by a difference in its market values at two different dates.

(2) *Diversion of Water.* It may be hardly necessary to state that, inasmuch as all flowing water, as a rule, is held appurtenant to real estate, when some or all of this flowing water is prevented from reaching such real estate, an act of what is called diversion has taken place, and this causes the damage in such cases complained of.

(3) *Market Value.* A sum of money that can only be arrived at by the opinion of a properly constituted tribunal from evidence put before it, or generally by a concensus of opinion of men having knowledge of market values, that is, of the values of such property as it is bought and sold in a market that is neither stimulated nor constrained; that is, in a natural, open market, as between a party ready to sell and another willing to buy.

At first it might seem to an engineer as though the simplest way to compensate for the diversion of water from a piece of real estate would be by turning an equal quantity of water into the stream from some new source of supply, such as a storage reservoir to be constructed for that express purpose, and which would supply, when needed, water which had been stored out of freshet river flow; which not only was not needed, but might even be detrimental to others, the claimant included, if not thus withdrawn and stored in times of high water. Especially does it seem strange to an American engineer that this method of paying for water diverted by the gift to the parties injured of a compensating reservoir, as it is called, is not followed in the United States, when he knows that for a hundred years or more this has been and yet is the accepted method in Great Britain.

Many years ago, not being able to cause any one, learned or unlearned in the law, to give a satisfactory answer to my inquiries on this point, I had to study it out for myself, and was obliged for this purpose to import several acts of parliament authorizing the construction of such compensating reservoirs. Acts of this sort,

being of mere local concern, are not likely to be found elsewhere than in Great Britain, even in the best of law libraries, but a reading of them is extremely instructive in more ways than one; among others as illustrating the gulf that separates the rights, duties, immunities, and privileges of the citizen of Great Britain from those of a citizen of these United States. From such an act of parliament it quickly appears that, whereas a citizen of the United States lives under a government in which the legislature may enact laws, but cannot act as a judicial body (except in cases of impeachment), nor perform executive work, and the judicial and executive branches of the government are similarly each strictly confined to its own branch of government work, "to the end," as says the constitution of the good old Commonwealth of Massachusetts, "that this may be a government of laws and not of men"; the parliament of Great Britain, on the other hand, has powers "so transcendent and absolute that they cannot be confined, either for causes or persons, within any bounds."

And we find, in fact, that parliament, through its committees, habitually sits as judge and jury and awards damages, when it considers private legislation, and puts its awards into the clauses of such acts; nothing of which work any of our legislatures nor Congress can possibly do. It is under these powers of parliament that compensation reservoirs have been and continue to be built in Great Britain, with minute directions how they are to be maintained and operated, and, if desired, parliament could itself operate them.

Then, again, the state cannot authorize any one to "take property without just compensation"; and it is a settled principle of law in this country that a "just compensation" must consist of money paid over, and cannot consist of anything else. Every person has, moreover, the right of an appeal to a jury of his peers and countrymen at some stage of the proceedings, to say what amount would be a just compensation, and cannot be deprived of this, his right of appeal. So that though such compensating reservoirs have repeatedly been proposed, and in one instance — some sixty years ago, at the time of the construction of the first (the Cochituate) water works to supply Boston — were actually built, they could not be used to pay damages by substituting water

delivered for water diverted. Whence it appears that, stating cause and effect in juxtaposition, we may say that when Montesquieu, in 1748, in his " Esprit des Lois " (The Spirit of Law) first stated the necessity in a free state of separating the duties of the legislature, the executive, and the judiciary from each other (a principle which, as is well known, was adopted by all the American constitution builders of the eighteenth century), he decreed that American engineers could not build compensation reservoirs to pay for water diverted.

At first glance this may seem a result that is deeply to be regretted, so perfect, physically, is the form of compensation for water diverted made by water supplied. But there is a good deal to be said on the other side, and, as usual, it is weak human nature that is at fault. The difficulty comes in the course of time, on account of failure to compel the responsible parties properly to keep in repair and operate the compensating reservoirs year after year without pecuniary interest in having it done, and on account of the manifold changes of value that take place in the life and interests of the people. So that, for one, I have come to the conclusion that Montesquieu, in 1748, builded wiser than he knew in the matter of compensation reservoirs, and that for a practical, live people the payment of damages in money, the full and complete settlement of damages as they arise, and by the generations as they pass across the stage of life, is the better way.

It has been suggested that a city, by obligating itself to maintain and operate certain compensation reservoirs, could show that it had not diminished certain water rights, hence that no damage had been done, and there would be no damages to pay. But a jury would have to decree to that effect; a riparian owner has the right to have the water flow through his estate " without alteration," whether he were injured or not, and even were he benefited for the time being. In the United States he must be paid damages in money if he wants them, and he generally does.

We have seen that a substitution of water for water diverted is unlawful and impossible in payment of damages in the cases we are considering. Equally so should be, but with uninformed tribunals is not always, the substitution of steam or other caloric or transmitted power for water power diverted. Such substitu-

tion offends against the rule of law quoted, which is based wholly on market values, and justly so, as will plentifully appear. Suppose, for example, that the water power taken were situated within the site of a storage reservoir, to be buried eventually under 50 feet or more of water. If now a computation were made for that case of any form of substitution of steam power, the whole of the water power being taken, it would result in a computed award made by the engineering expert that would have no proper relation to and might be twenty or thirty fold the market value of the real estate taken, either before or after the diversion of the water under consideration. That is to say, it would have no application whatever to the case in hand; it would be wholly irrelevant and out of place for the expert to give it, and going further, he should know or be taught that such testimony is not aiding the court in its work. And if such testimony is wholly wrong or mistaken in one such case, because it does not instruct as to market values, the like testimony in other cases, if of no instruction in market values, is equally improper and may be grossly misleading.

Here, indeed, is the true test of such scientific or engineering testimony: Will it instruct experts in market values, or has it no readily discernible connection with market values? If the former, it is good; if the latter, it can only mislead.

Other cases repeatedly come before the masters in such cases in which the estimated values of substituted steam power have no direct bearing or give no instruction upon market values before and after the taking of the water diverted.

Such are the damages to an undeveloped mill site; to a mill driven wholly by water power in a place where steam power is a practical absurdity, and many more. There is every degree of bearing upon market values of testimony relating to steam power; from cases of no bearing at all of the cost of a substitution of steam power, such as have been cited, to those of the cost of a little extra coal burned on account of a minute percentage of diversion, which, in the mind of the buyer and seller in the market, may form an approximate indication of effect produced; from which, again, by a concensus of such opinions, the effect of the diversion on the market value may be arrived at.

If the rule of law first above quoted is good, it must be applied to all cases of damages to real estate by a diversion of water. It cannot be ignored where palpably it will not apply,— such as in the case of the reservoir site above referred to, or of the place where steam power is an absurdity, or of the undeveloped mill privilege,— and then adopted and values of a substituted steam power used in other cases.

If it is a rule of law, as we are told it is, it must hold in all cases; not have one law for the rich in opportunity and another for the poor.

Strictly speaking, all such cases require two distinct sets of experts, the one to measure the damage done in horse-power diverted and similar damage done; the other, consisting of assessors, real-estate agents, parties who have bought and sold mill property in the vicinage, etc., to appraise the value of the property before the diversion, and to appraise what that property was worth in the market since the acts complained of had taken place; which latter appraisal they may properly base on the results of the computations made by the first-named set of engineering experts.

Engineers with experience in cases of this class know that claims of ten fold and twenty fold the awards finally made, and of a *twentieth part of a water right* being computed worth more than the *whole piece of real estate* originally was worth, are no rarity, and are based on the computed cost of a substitution of steam power, capitalized, for the water power diverted. Engineers are responsible for the appearance of such claims in such cases, which would not appear and could not appear under a consideration by them of market values and of the rule of law noted. So absurd have these computed damages been in the past, being based simply on the capitalized cost of a number of horse-power equal to that of the water diverted, that able engineers, Mr. Main as a leader among them, have mitigated such computed damages by assuming a certain steam power present, and computing merely the cost of the additional fuel or power needed, after the diversion has taken place, to maintain the former total output of power per annum. This undoubtedly is more instructive as to the effect of the water diversion on market values, for the market is composed of both

buyers and sellers, and the average man in the market is, after all, Carlyle to the contrary notwithstanding, no fool out of the "1 500-000 000 inhabitants of the earth, mostly fools." But the principle must not be lost sight of, that we are establishing in the trial of such cases *two market values*, and the business of the engineering experts is to aid the appraisers of such values in the case in hand to reach a conclusion on market values; and it is not for the engineers to compute what the damages in dollars and cents in such cases may have been if based on any form whatever of substitution of steam power for water power; any more than it is to estimate the cost of bringing in additional or substituted water power or transmitted electric power, or any other power, and calling that the measure of damages. If the results of computations offered do not square with sensible market values, this will constitute proof positive that the methods which were followed by the computer were in error, and hence that they can not with propriety be used by him or any one else.

Closely allied with this subject is the broader one of the "Best Use to be Made of Experts in the Conduct of Judicial Inquiries." It would lead too far, however, to attempt here a discussion of that subject. It was treated at length by the present writer in 1886 in a paper which was printed by "Direction of the Committee of the Bar Association of the City of Boston on the Amendment of the Law."

If this class of cases were more frequently tried in any one community, the awards to be made would, no doubt, speedily reach a normal measure. That is to say: — within limits, a market value for such damages would become established. Nothing might at first seem more fanciful than to expect an established schedule of damages adopted for the loss of a limb, or an eye, or other member. And yet the Pension Bureau, which deals with such cases by the hundred or thousand, has adopted such a schedule; so much for a right leg gone below the knee, another price for the whole leg, one price for the left eye and another for the right. Similarly it may be said that these mill damages in the last forty years in the New England states, when not notoriously excessive (they do not often err by being notoriously too small), have ranged from $50 to $100 or $125 per million gallons per day diverted, used

on one foot of fall. From which the value of a stated quantity of water diverted, used on any stated fall, may be judged between limits, or approximated, but taking into consideration all the attendant circumstances of the case in hand.

WATER RIGHTS.

BY RICHARD A. HALE, PRINCIPAL ASSISTANT ENGINEER, ESSEX COMPANY, LAWRENCE, MASS.

[*Read September 12, 1907.*]

The subject assigned to me to present this morning covers a very wide range of details, any one of which would easily occupy the allotted time. As the previous speaker has discussed the diversion subjects so thoroughly, I will confine my paper largely to the general subject on which the diversion matters depend.

In all diversion cases the main point to be first ascertained is the water rights of the company or individual, and what water and power can be depended upon before any diversion takes place. Water rights in general at any mill privilege comprise the use of the water for power and various manufacturing purposes, and when controlled by one individual or company no serious complications are liable to arise. When, however, the power is owned by several parties, questions may arise producing serious entanglements in the subdivision of the water, especially during the dry periods of flow. The early deeds relating to water rights were often vague and indefinite in relation to the subdivisions. A few examples will illustrate my meaning. The Essex Company, controlling the water power of the Merrimac River at Lawrence, leases the water in " mill powers." A mill power is the right to draw from the nearest canal or water course so much water as shall give a power equal to 30 cubic feet of water per second when the head and fall is 25 feet, to be drawn sixteen hours per day. As the height of water varies with change of seasons, the quantity of water is varied in proportion to the height, one foot being deducted from the height of the fall and also from that with which it is compared before computing the proportion between them; thus

for any fall the quantity of water to make a mill power is

$$\frac{750 - 30}{\text{Fall} - 1}.$$

The one foot is allowed for the loss of head in reaching and leaving the wheels. This definition of a mill power giving a constant power is explicit, and during the sixty-one years in which it has been in use, has admitted of but one interpretation and has never been questioned. The leases at Lowell, Holyoke, Turners Falls, and Bellows Falls are written on the same general lines, although in one locality the quantity of water is not varied in proportion to the fall as the fall changes. At Cohoes, N. Y., the "mill privilege," as it was called, was the right to draw from the canals of the company 100 square inches of water when the head and fall is 20 feet, that is, 3 feet head and 17 feet fall, to be drawn through a gap of cast iron or other metal having an aperture 2 inches deep and 50 inches in length, with the edge of the aperture not less than 1 inch in thickness; and in the same ratio for a head and fall greater or less than the above named.

Mr. J. B. Francis, the eminent hydraulic engineer, by agreement of the various mill owners, made experiments in 1859 with a head of 3 feet acting on the center of this form of orifice, and ascertained the quantity to be 5.9 cubic feet per second. Shortly after this, new proposals fixing 6 cubic feet per second on 20 feet fall were adopted for all future sales of water power.

Not all rights are so clearly defined or settled as those above mentioned, and a few examples are given of more obscure rights. One of the most prominent cases is the "Smith's Pond" water rights at Wolfboro, N. H., involving one dam at the outlet of the pond and two other dams just below on Smith River. Tradition says that disputes began in 1778 and have been waged at intervals ever since. However that may be, the quarrel began again in 1896, and at date of this writing matters are still before the court. The main questions were the rights in using the quantities of water from Smith's Pond at various times and the amounts that could be drawn throughout the year. With several different interested owners, and not very clearly defined water rights, the case has dragged along encumbered with legal questions, with no

immediate prospect of settlement. The writer and the late Mr. Freeman C. Coffin were associated with the case in the early days, but withdrew two years ago, feeling that little progress was being made towards settlement. Mr. Arthur T. Safford, consulting engineer at Lowell, Mr. H. D. Mears, and Mr. Lewis D. Thorpe have been called in at various times. One principal question which could have been settled if left to the engineers was the yield of the pond with storage, to see what could be drawn in various periods of the year. Definite observations were not taken in such a manner as to arrive at satisfactory results. The rights of the parties varied. One owner had the right to run when the pond was full, and others had rights to drive certain machinery. Estimates and measurements of the various water wheels were made with the quantity of water that was used and subdivisions made of the water. The hydraulic problems involved the amount of water that could be conveyed by certain sized penstocks, estimates of water necessary to drive wood-working machinery and grist mills, and the probable discharge of an old-fashioned tub wheel.

A more recent case, which involves various water rights in Hinsdale, N. H., may be of interest as being applicable in many places. A company was formed in 1839 in Hinsdale for the purpose of building a dam, canals, etc., and developing power for manufacturing purposes. Eight persons were interested in the scheme and owned the power in certain proportions measured by square inches. Various questions arising in regard to the quantities of water, in 1859 bulkheads of plank were placed at the entrances to their flumes. and orifices having the areas of their legal number of square inches were made in the bulkheads, at the proper distance below the surface of the water in the canal, by a legal decree of the court. The number of inches and head were very definitely stated, but thickness of the orifice plate was not mentioned. One party was entitled to the surplus in the river after all others had been supplied with their legal rights. In 1867 it was agreed by the manufacturers that the canal should be enlarged to carry an increased quantity of water, and to improve the general conditions of water power, and $1 500 was expended in this manner. It was also agreed that whatever increase was obtained should be divided *pro rata*, according to the number of

square inches owned by each party. At about this date the upper portions of bulkheads were removed and water was drawn over the top with no reference to orifices, and the amount of water drawn was limited by the capacity of the water wheels. In the year 1885 suit was brought, by parties owning the right to surplus, to compel the restoration of the upper portion of bulkheads, but nothing definite was accomplished. In 1905, owing to changes made by parties owning the surplus, a suit was brought against them by the remaining owners on the grounds of excessive use of water. The rights of all parties were to be determined. The writer had made some investigations for the parties entitled to the surplus, and the late Freeman C. Coffin was engaged by the other parties to the suit. As there were many hydraulic problems involved and engineering facts, that it seemed unnecessary to work up in duplicate, which would have to be ascertained in a suit in court, the writer suggested that the engineers should consult together and make a joint report. This was agreed upon by all parties, and the court appointed Freeman C. Coffin and the writer as engineering members, and Hon. J. H. Frink, counselor-at-law of Portsmouth, as the legal member of the commission. The commission were to hold hearings and make a report to the court as to the amount and the methods of drawing the water to which each was entitled. Several hearings were held, and testimony was given in regard to enlargement of canals and past use of water, and a report was made giving the amounts of water to which each was entitled under varying conditions of flow. The main problem was to determine the surplus previous to 1867, and what additional surplus was gained by enlarging the canal at that time, which was to be divided among the owners. All additional surplus belonged to the eighth party. The questions of the yield of the stream and capacity of the canal were considered and the fact that the parties had used the water for a long period (about twenty years), without remonstrance, was given weight. A system of measuring weirs was recommended and adopted by which each party should draw the amount to which it was entitled. As the parties were not entitled to quantities of water on an equal basis, but certain ones had priority over others, it was necessary to adapt the lengths and heights of the weirs to fit these conditions as far as possible.

Various adjustments were made after the weirs were placed in position. Another difficulty arose from the fact that the surface slope in the canal varied with varying quantities of water, necessitating heights of weir crests which were correct for one quantity and not strictly accurate for another. By experimenting with varying lengths and heights of weir, the quantity which each was entitled to draw was decided with a fair degree of approximation. For very small flows, tables of heights were given, showing when parties should cease drawing in the order of their decreed rights. Two of the rights have been combined, making one party less in the final division. In the later years no special efforts were made to maintain the rights of each owner, which, if maintained in a systematic manner, would have avoided the extensive investigation and adjustment. An objection to the use of measuring weirs occurs in the fact that they reduce the available head on the wheel. One other plan was proposed, that of attaching gages to the wheels and from the fall and openings regulating the quantities. This would require much more detail, and the owners preferred to lose the head during the low period of flow and have an automatic measurement rather than to require so much detail by the other method. During the period when water was abundant there was practically no head lost. Before the final report was made, both Mr. Coffin and Mr. Frink were removed by death and Mr. Lewis D. Thorpe, a partner of Mr. Coffin, who was familiar with the details, was appointed to fill the vacancy caused by Mr. Coffin's death. It is hoped by all parties that the matter is finally settled after long and tedious investigations.

Another case in the same locality occurred where a woolen mill and paper mill were on the same dam and the power was divided in the proportion of two thirds and one third of the flow of the river. As the paper mill used water for twenty-four hours, and the woolen mill for ten hours, various complications arose, and the matter was finally adjusted by measuring weirs dividing the flow of the stream proportionally. The storage capacity was very small above the dam and the vexed question of the difference in use of ten and twenty-four hours did not receive a weighty consideration.

The above examples have been stated somewhat in detail to

illustrate the importance of water rights being clearly defined when various parties are mutually interested, and also to illustrate the complications that may arise from neglecting such details.

As previously stated, in water diversion cases one of the main questions is to determine the amount of water which can be depended upon for power and the general flow of the stream. Most manufacturers have a general idea through their master mechanics of the amount of power at their mill privileges, but it is often stated in such a general way that it is not of value to an engineer as an accurate record. A system of keeping records of the flow of the stream at a small water power is not a complicated matter, and very valuable data may be collected without great expense. The general outline of the method is to use the water wheels as water meters and the overfall of the dam as a weir to measure the amount not drawn through the wheels. The Hydrographic Department of the United States Geological Survey has used this method, and various papers relating to the flow of streams and methods are familiar to all engineers engaged in hydraulic work. Messrs. R. E. Horton and H. K. Barrows of the Geological Survey have made special studies and reports on these general lines. A brief illustration is presented of the method as used at the Marland Mills, Andover, where measurements on the flow of the Shawsheen River were conducted for three years. The plant was a 14 set woolen mill with a breast wheel and a turbine situated on one side of the river and a second turbine on the opposite side of river. A separate flume led the water to each wheel. Gages were established in various locations, and the crest of the dam was fitted with a planed plank set at a uniform height (by a leveling instrument) to measure the water which wasted over the dam. All gages were set to a uniform datum plane and distributed as follows: The gages consisted of white pine boards 6 inches by 1 inch, painted white and marked in feet and tenths and half tenths and secured to posts attached to wall. One was set in the pond above the dam, which was used for obtaining the depth on crest; others were set in each forebay or flume above the wheel, to use in obtaining the fall on the wheels; another series were set in the raceway, to show the height of water after leaving the wheels. The difference between the two readings showed the fall on the

wheels. The total amount flowing in the river was then the sum of the following:

1. Amount wasting over dam.
2. Amount drawn by wheels.
3. Amount used for manufacturing purposes, such as dye house, boilers, etc.

1. The amount wasting over dam was deduced from the depths shown by the pond gage. Owing to the shape of the crest, the Lawrence dam formula applied to good advantage. An ideal apparatus would have been a self-recording gage to show a continuous record, but at this period, twenty-five years ago, such gages were not as available as at the present time. Readings were taken by the carpenter connected with the mill at intervals of two hours during the day, and the watchmen took a height in the evening, and one in the early morning, which were assumed to give a fair average of flows during the night. The readings were plotted with heights and times of observations on cross-section paper, and a line joining the observations showed the range above the dam. From the average line the amounts wasting during working hours and outside of working hours were determined. In this particular instance the working hours were from 6.30 A.M. to 12 M., and 1 P.M. to 6.30 P.M., stopping at noon Saturday. As additional to the convenience of this division, it indicated at a glance what water was available, if any, for an extra wheel at any portion of the year and the value of the pond for storage purposes. The ratio of the waste to the total flow and other interesting comparisons were deduced.

2. The amount of water drawn by turbines. In using the wheels as water meters, it is necessary to ascertain their discharge at various openings of the speed gates. The Holyoke tests form an excellent basis for these data. Changes in form of buckets and guides of wheels and outlet areas, variation in lengths and size of draft tubes often change the discharge, and it is desirable to measure the water as actually used by each wheel. If the wheel is running in connection with a steam engine, as is frequently the case, measurements may be made at various gate openings, thus determining the discharge, from which tables can be made. To determine the opening of the gate, a convenient method is an iron

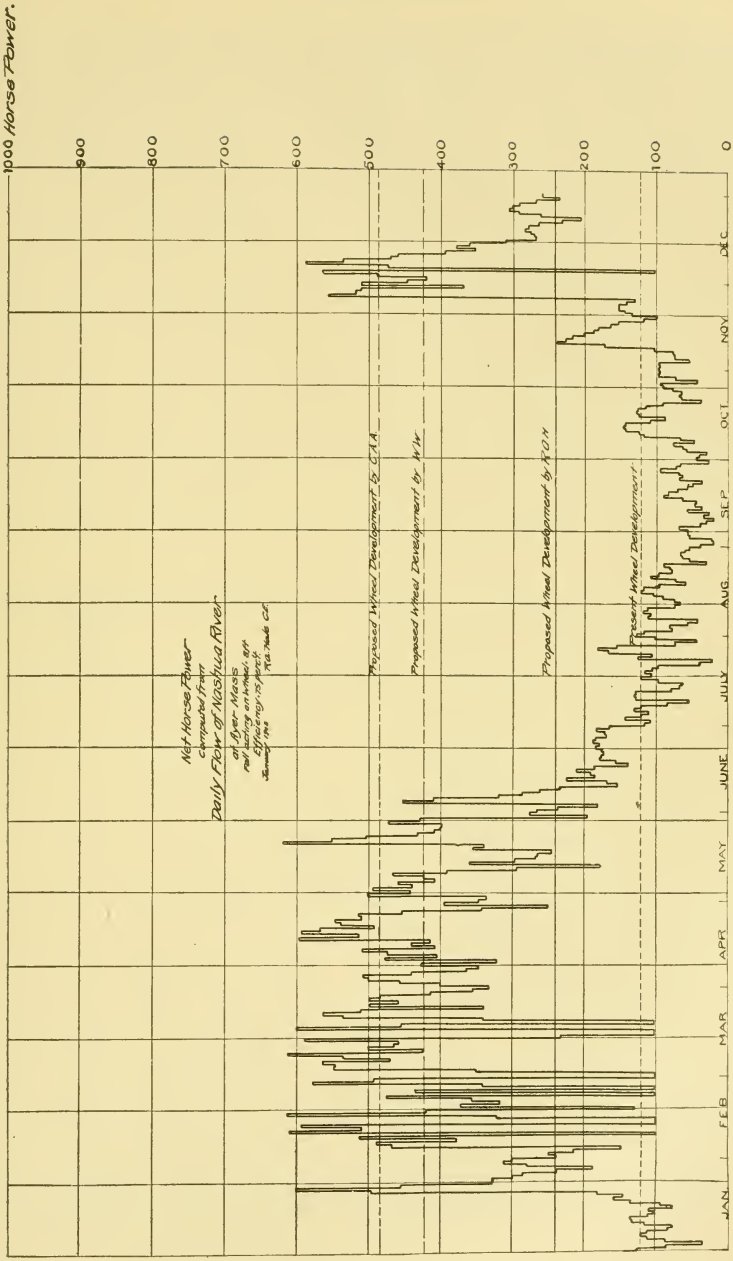
or brass rod attached to the rack iron of the speed gate and of sufficient length to project through the wheel case where a scale divided in feet and tenths shows the amount of opening. Dial gages and pointers may be used if more convenient.

Measurements of water may be made by submerged floats or current meters in rectangular flumes or by weirs in the raceways. Diagrams of discharge show graphically the amounts discharged at various gate openings and falls acting on the wheels. At the Marland Mills the wheels were measured by submerged floats and weirs, and tables calculated for other falls than those observed. The heights of the speed gates were observed at intervals during forenoon and afternoon, and an average height used in determining the flow. The number of hours was noted that the wheels were run, as during the dry period it was necessary to shut off wheels a portion of the time. Wheels run at noon hour were recorded, and water used in the dye house and for scouring was measured at a separate outlet. Combining the quantities for the periods for which they were drawn gave the yield for twenty-four hours. It was necessary in measuring the quantities outside of working hours to ascertain the leakage from wheels and various pipes in dye house, etc., accurately, as this often formed a large percentage of the flow during a dry period. A similar system can be readily adapted to any mill privilege and records kept with but slight expense. The results in connection with rainfall on the area are of great value in the knowledge of the yield of the stream and its value for power. In these results the valuable data thus obtained show how the flow of the stream is distributed throughout the working hours and outside of working hours, and the amount available for actual use. The percentage of waste which cannot be utilized on account of lack of storage, sudden rains, and variable use by other parties on the upper portion of the stream is always a question of discussion in water division cases. The amount of 10 to 20 per cent. is often used in diversion cases and is a reasonable amount. The storage capacity is a large factor in this matter, and in Lawrence, on the Merrimac River, with considerable storage there has recently been a period of a month when no water was running over the dam. On a smaller stream the range of percentages of 10 to 20 per cent. would be reasonable.

It is often possible to place a gage in a stream unaffected by dams below, which should give a correct index of the quantity of water passing. The quantity of water must be measured with various readings of the gage and a diagram constructed showing the actual quantity flowing at various heights. For the flow of twenty-four hours a continuous record of the gage must be taken and the average height for that period taken. If the water power is used chiefly during the ten working hours, a reading of gage taken during period of steady flow may be used after ascertaining its relation to the average for twenty-four hours.

The records of a large water power, as the Merrimac River at Lawrence, are kept in the same general methods, but necessitate more details. Flashboards on the dam are kept in good condition and levels are taken on the crest of the boards at intervals so that from the depth flowing over the boards the quantity of water may be computed. Outside of working hours the head gate openings furnish a means of measurement in the canals and various leakages through wheels and waste gates, etc., are measured and combined in the twenty-four-hour flow. The results are of value to show what extra water may be depended upon if surplus is desired. A gage is located in the river near the lower end of canal and readings of this gage indicate the quantity of water flowing as ascertained by previous computation. During the period of ice floating in the river when the flashboards are broken and pins bent over, it is necessary to use this gage in ascertaining the quantities. These periods are quite infrequent and in general the more exact methods are used.

In the customary method of ascertaining the yield of a stream, the average of the driest months is taken for a series of years, then the next driest, and so on. This is preferable to the calendar months where a wet January of one year would be averaged with a dry January of another year and present misleading figures. After a manufacturer has collected his data showing the average yield per month, the power can be computed and the average power for the year ascertained. Another table can be arranged showing the conditions after a portion of the water is diverted, and the difference shows the average loss for year. In computing the power month by month it will be borne in mind that wheels are


1000 Horse Power.
900
800
700
600
500
400
300
200
100
0
Net Horse Power
computed from
Daily Flow of Nashua River
at Ayer Mass
Proposed Wheel Development by C.A.A.
Proposed Wheel Development by W.W.
Proposed Wheel Development by R.O.H.
Present Wheel Development
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEP
OCT
NOV
DEC

1900

FIG. 1.

generally installed to use the capacity of the stream up to the eighth month. There are periods of large flows and reduced heads when a wheel may be used supplementary to the regular power, but whether it is a profitable investment to run four months and to remain idle during the remaining eight months must be considered. In the use of turbines the efficiency is reduced on very low flows; the speed gates are open a small amount and the efficiency is poor. After diversion occurs, the smaller quantity that is left will be used with less efficiency on the turbines and this loss is often very appreciable. If great difference exists, it may necessitate new wheels of other capacities to be adapted to the new conditions.

In some diversion cases where daily flows have been observed, a diagram showing the available horse-power for each day before and after diversion and the capacity of the water wheels illustrates the actual condition without involving a series of averages which smooth out the irregularities. An example is shown in Fig. 1, the

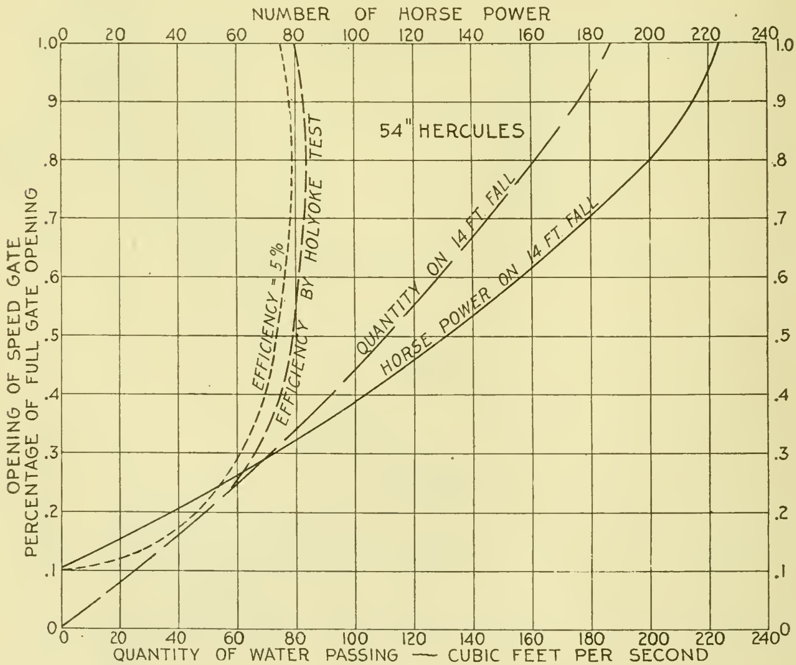


FIG. 2.

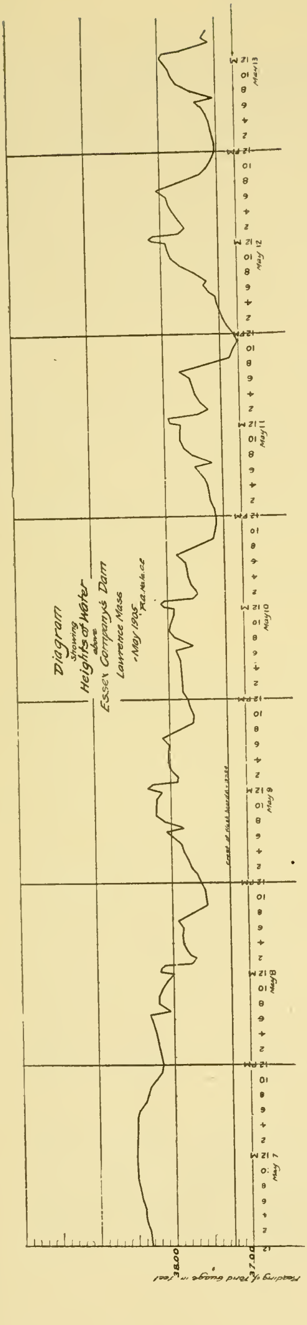


FIG. 3.

diagram of daily horse-power at Nashoba Company on Nashua River, which shows the variations in horse-power which exist in the variable flow of the stream. The necessity of installing a steam plant to supplement the small amount of power obtained during the dry months is shown by the large area between the various wheel developments and the actual power. During sudden storms and rises of the river, water is lost by wasting as indicated by sudden rising in the spring and fall. The lines shown for wheel development were used by various engineers in the diversion case.

Diagrams for obtaining graphically the horse-power from the wheels, percentage of efficiency, etc., with the quantities of water discharged at various gate openings, are useful in presenting the cases, and an example is shown in Fig. 2. In Fig. 3, the diagram of height of pond above dam at Lawrence is plotted from hourly observations and the range of heights of water shown by the irregular black line. The horizontal line shows the crest of flashboards. An average height is taken for intervals of one or more hours, depending on the variation of heights. The quantity of water is computed from the J. B. Francis weir formula, or, if the flashboards are gone, the Lawrence dam formula is used.

The financial damage from the diversion of the water varies with the condition of each case and no fixed general rule can apply. With combined steam and water-power plants and varying conditions in the use of steam and engines, a special investigation must apply in each case. The general expenses connected with the engines and maintenance are well known and can be ascertained from well-kept records. The general expenses of water-power maintenance vary in each case. Repairs on dam and canals, care in winter for anchor ice, snow storms, etc., often increase the expenses materially.

I have preferred to deal with this branch of the subject without taking up the subject of financial damage due to diversion which would extend the paper to an unreasonable length and has already been ably presented. It should be stated, however, that the manufacturer should receive a fair compensation for the water diverted and the expenses of running by steam and water considered and a sufficient sum be paid to cover the annual loss which exists.

DISCUSSION.

MR. H. K. BARROWS.* Mr. President, I have little to say, except to express my general interest in the subject. Mr. Main's paper interested me in the matter of wheel capacity; that is, the amount of horse-power or the number of wheels that should be installed in a new plant. Some data on that subject would be of interest, showing how installations vary for different uses. For instance, in the case of pulp and paper manufacture, installations are often made for two or three times the amount of water expected during eight or nine months of the year, the idea being to use this excess installation in grinding the pulp when there is plenty of water, and then later on using the pulp in the process of paper manufacture. Perhaps Mr. Main could give us a table showing about what he considers to be the proper wheel capacity for the different types of installations.

The matter of keeping a record of flow is, of course, one that has interested me greatly, and frequently it can be done, as Mr. Hale has said, with little expense to the mill owners, furnishing informa-

* Civil Engineer, Boston, Mass.

tion of great value. It is too often the case that when this information is very much needed, it is not available in questions of water rights or in improving a plant, as these records must be obtained over a series of at least a few years to be of conclusive value.

In the adjustment of the flow of water and the consideration of water rights there is a further division of the subject that has not been mentioned, *viz.*, that of securing and operating additional storage and apportioning the cost of this among different mill owners upon the river in question. The common situation, on such of our New England streams as furnish good natural facilities for storing water, has been that some one of the power users on the river has acquired control of this storage and operates it; usually, however, to the benefit of others on the river, and with no cost to these others. The time is approaching, however, when storage of water for power use during the low-water season will be attempted on a larger scale; and to make this profitable, the expenses of construction and maintenance must be borne by all who are benefited.

The necessity of careful and systematic regulation of flow from storage reservoirs has in many cases not been realized. Thus in the State of Maine the three large power streams, the Kennebec, Penobscot, and Androscoggin, are naturally equipped with lake systems, well up in the head-waters, which furnish admirable facilities for storing water. The development of this storage has, however, been slow, and, until within a few years, almost entirely for purposes of log driving. The Kennebec River is especially well equipped with lakes and ponds, comprising Moosehead Lake with 115 square miles of water surface, and the numerous other large lakes of the tributary Moose, Roach, and Dead rivers. The regulation of Moosehead Lake, at present the only one of these lakes used to store water for power purposes, is in the hands of the Kennebec Water Power Company, which company is made up of the principal owners and operators along the main river.

Log driving and lumbering interests in this river are represented by the Kennebec Log Driving Association. As these two companies are made up largely of the same parties, the present control of the lake storage is entirely harmonious. Log driving, however,

requires a large amount of water, and at times when it should be stored for power uses. No systematic regulation of flow from Moosehead Lake is maintained and much water is wasted, especially during the log-driving season. The speaker has shown in the case of Kennebec River * at Waterville, where some of the large power interests are situated, that during the period of 1893–1906 a low water flow, never less than about 2 500 second feet (depending upon what assumptions are made for water used in log driving), could have been secured, by a proper control of storage facilities at *existing* dams. As a matter of fact, a mean monthly flow as low as 921 second feet was reached at Waterville during February, 1904, showing how little attempt has been made to regulate flow on a river where large power interests are already situated.

The development and control of water power is now being considered by several of the states. New York, for example, under the "Fuller Bill," has recently passed an act "authorizing and directing the state water supply commission to devise plans for the progressive development of the water powers of the state, for the public use, under state ownership and control"; Pennsylvania and New Jersey have also enacted laws relating to state control of water resources. The water-power project of to-day is coming to be more and more one involving storage, and some interesting questions of water rights and assessments will be brought about by state control, in the apportioning of betterments occasioned by storage, among existing water powers.

It seems reasonable to predict that our rivers in the future will be "operated" by means of storage reservoirs, as far as can be done with economy, — conserving the spring and fall floods to provide water for power users during the periods of drought, and incidentally preventing disastrous floods. Whether state or national control will be needed to properly carry this out and develop our water resources as they should be, is a question of great interest and importance.

Mr. Leonard Metcalf.† I have listened to these papers with much interest, and one or two questions have occurred to me;

* See Water Supply and Irrigation Paper No. 198, U. S. Geological Survey.

† Consulting Engineer, Boston, Mass.

one particularly along the line raised by Mr. Barrows, — a question which I thought of asking Mr. Main and Mr. Hale, — whether they chance to know of any cases in which settlement has been arrived at through the payment to the mill owners "in kind," that is, by the development of the storage facilities of the drainage area, other than the mill ponds would supply, by joint action of the interested parties or by one or the other of those parties.

It was suggested to me by a case in which Mr. King is interested at the present time, in which I made some figures which tended to show that the storage developed upon the head waters of the stream actually benefited the owners who were suing for the diversion of water. Yet the owners succeeded in getting a small award. The litigation isn't over yet, and we have hopes at least that the award will be very small. It certainly opens a very interesting field of thought, and it seems to me that in some of these water diversion cases it is the natural and the most equitable solution of the problem. Whether we can get the lawyers and the courts to take that view of it or not remains to be seen.

I also want to ask Mr. Hale one question about the Nashoba privilege development. I understand that since the litigation the dam at this privilege has been rebuilt, and that power is being developed for a certain traction company. It might be interesting to know to what extent they actually do develop the privilege,— in other words, what wheel capacity has been installed at that point.

Mr. Hale. I do not know just what capacity of wheels they put in, but I understood that they spent $100 000 in the new dam, flumes, penstock, and so forth, there. It seemed, in general, a very large amount per horse-power on such a low fall as existed there, and I have been intending to determine the exact amount at a later date. I ought to have added, perhaps, in the course of my remarks, that Mr. Metcalf was one of the commissioners in the Nashoba case that was adjudicated. I think we should be very glad to hear any additional points in regard to that.

Mr. Metcalf. Mr. Chairman, perhaps there is one thing I might say in regard to that case. I think commissioners are usually rather wary about discussing cases which have been decided by them and the elements which weighed in the decision. I think it

is fair to say of this case, however, that the low head at this privilege was a factor in the decision.

The head was 8 feet, and at times of flood and in the high water season that head is cut down to about 6 feet, as I now recollect the figures. Of course, under these low heads the question of the regulation of the speed of wheels is an important factor in the proper operation of the generator, if electric power is developed. I should say that the regulation of the speed is much more difficult, and the variation in the speed becomes more serious in the operation of the privilege, and that fact weighed in the award which was finally made.

The valuations in this case on the part of the several experts ran from about $10 000 to $130 000, — that is the estimate of the damage due to this partial diversion,— the engineers for the Commonwealth giving estimates of from $10 000 to $15 000, and those for the company of from about $85 000 to about $120 000 or $130 000, as I remember the figures. The award was $25 000.

Mr. Hale. I might add a word in regard to Mr. Barrows' statement about storage. Some two years ago that matter of storage was taken up in New York, with reference to storage basins on the Batten Kill and other rivers, with the possibility of ascertaining if the floods at Troy and at other places could not be reduced by arranging such storage.

I attended a hearing before a commission at Albany, and it looked at that time as though the prospect was very good for something being accomplished. The commission was inclined to take the matter up, investigate it, and build some storage basins, and would coöperate with the mill owners, to the extent that the state would pay a certain percentage. I don't recall now whether it was 40 per cent. or 50 per cent., but it was something like that. The mill owners would pay in proportion to their power — or fall. They had a few hearings, and I think the matter was then declared unconstitutional, in regard to development along that line, — that the state couldn't go into it,— and the matter was dropped.

I understand that since that period they have been taking it up again. The mill owners on the Batten Kill are now agitating the question of building storage basins. I have been formulating an arrangement by which a company might be formed, so that

an agreement might be made by the various parties to do something and bear proportionally the expense. Whether it will come to anything or not, I don't know.

Mr. Metcalf. Do you chance to know, Mr. Hale, whether it is a fact or not (I believe it is a fact) that on the Blackstone River —or on one of the streams flowing into it — that very thing has been done by the Draper Company or some other mill owners?

Mr. Hale. Storage?

Mr. Metcalf. Yes; by the construction of the Echo Lake dam.

Mr. Hale. I don't happen to know of that.

Mr. Metcalf. I think that it was the case that the mill owners coöperated and built this dam for the storage of the water, and that the cost was met by the various mill owners. Whether they all entered into agreement or not I do not know, nor do I know the expense involved in the work.

Mr. Hale. The question on the Batten Kill in regard to the mill owners was in what way they should be assessed. The natural way would be in proportion to the fall, although in case of some of the falls which were not fully developed, or were undeveloped, the parties felt as though they shouldn't pay a proportional amount. That would be something to be agreed upon among them.

Mr. W. C. Hawley.* Mr. President, as a matter of interest along this line I might say that when the city of Troy was considering the Batten Kill supply, some twelve years ago, it was found that in order to get the water to the distributing reservoir a ridge had to be crossed, and that there would be 10 000 000 gallons per day with an available head of something like 200 feet from the top of this ridge to the distributing reservoir. It was proposed then to develop this power and supply electric power to the various mills whose horse-power had been reduced by the diversion of this water. The scheme was worked up to a point where we considered the legal end of it, and it was decided that it couldn't be done under the existing laws of the state of New York, and for that reason was given up.

It would have more than replaced all of the power which was

* General Superintendent, Pennsylvania Water Co., Wilkinsburg, Pa.

taken from the mills, and would have given the city of Troy considerable power available for street lighting, and so forth.

Mr. Main. In answer to Mr. Metcalf's question I would say that during the time the Worcester cases were under consideration —the Kettle Brook cases—it was suggested that that very thing be worked out and presented in evidence, and Mr. Freeman C. Coffin was employed. He did a considerable amount of work along those lines, but counsel for the city decided that it wasn't proper to put it in, so it was dropped. I understood at that time that in England it was lawful to pay in kind,— to build a compensating reservoir and to supply as much water as had been taken away in that way, but that it couldn't be done in the state of Massachusetts.

Mr. Kenneth Allen.* Mr. President, several years ago projects for an additional water supply for the city of Norwich, Conn., were taken up. I am very sorry that Mr. Chandler is not here to read his paper, because I thought, being fully acquainted with the circumstances, he would probably touch on the question of compensation in kind in that connection.

The firm to which I belonged at that time made an investigation and recommended compensation to the mill owners below the proposed reservoir by paying in kind. There were a number of mill properties below the watershed that would be affected, but we showed to our own satisfaction — if not to that of the mill owners — that they would be bettered by the improvement.

As a matter of fact, this proposed supply was about 7 000 000 gallons a day, while with the old supply they were getting about 2 500 000, and we considered that, with the natural growth of the town, the city would be justified in expending the amount of money necessary to provide the larger supply. As a matter of fact their bond issue, I understand, was limited to a certain amount, which wouldn't quite pay for this, so that the works were never built.

I was very much in hopes the matter would come to such a point that it would be shown whether this could be put through. I understand the mill owners maae a claim for damages of about $100 000. That added to the cost of the works would probably have been prohibitive.

* Division Engineer, Baltimore Sewerage Commission.

There is one question I should like to ask, and that is whether there has ever been any consideration of damage to a lower water right on account of *pondage,* this being in the nature of a damage rather than a compensation; that is, pondage, rendering uncertain the supply of water to a lower mill, would naturally act as a detriment rather than an advantage in operating the said mill, for which damages might be demanded.

Mr. Main. I was going to add that too much weight could not be placed upon the use of very definite terms in the division or appropriation of water rights to determine the amount of water to be used by different parties upon the same privilege.

Two very interesting cases have recently come to my notice, one of which I have worked out and the other one I have not been able to work out yet.

A short time ago I was called upon to see if a certain party was using more water than properly belonged to him. The terms of the deed were something like this:

It was dated in 1872. It stated that the mill connected with this privilege had the right to use as much water as would be required to run 200 cotton looms, and the complement of other machinery, on a wheel not less efficient than a good breast wheel.

Fortunately, the shafting had not been removed from the mill and I was able to determine from that and from a workman who had been in the mill some forty years, the width of the looms used and the kind of goods produced. From this, I determined how much machinery was required, and how much power was required to run it, and after determining the efficiency of a good breast wheel in 1872, I was able to determine the amount of water to which the privilege had a right.

In the other case, the deed was written in 1861; the party had a right to use as much water as would be required for a 10-set woolen mill for power and manufacturing purposes.

To determine the amount of water, it was necessary to ascertain the greatest width of card used in 1861 and to work out the organization of a 10-set woolen mill, based upon such width of card, and to determine the maximum amount of power required for a 10-set woolen mill and the amount of water required for power and for manufacturing purposes for the same.

Deeds written as indicated above are very indefinite and when written to-day should designate the amount of water in cubic feet per second to be drawn, so that there will be no question about the amount.

Chairman King. Mr. Metcalf said that the statute required that the dam be built above the privilege, so there is no question about providing for the storage. The question is of the offset for damage. Another question arose in that case — perhaps Mr. Metcalf looked into it — where different parties were taking water from the stream, one below the other, of course, where they formerly all drew water in the daytime. Then, by a change, the water went into the hands of an electric light company, and they use the water in the night. Whether there is anything to be said upon that subject, — perhaps Mr. Metcalf looked into that question.

Mr. Metcalf. I don't know, Mr. Chairman, that I have very much to add on that matter. It seems to me the question of pondage — the same question to which Mr. Allen has alluded — is a very vexed one, — one on which we haven't had very definite decisions, beyond the fact that the courts have ruled that reasonable use on the stream should be considered. Just what reasonable use of the waters of a stream, or just what that term means, is, perhaps, a little vague. In the case to which Mr. King refers, I stated in my report:

"It is evident from the small flow of this stream during midsummer, that there are times when substantially the entire twenty-four-hour discharge may be impounded within the mill pond of the electric-light plant and utilized during the evening hours of peak load at the plant. Under these circumstances, since the mill pond of the next privilege is probably considerably smaller than this mill pond, and hence would not be able to store the entire quantity let down at night by the electric-light plant, and thus make this water available for operating purposes upon the following day, — the court would probably construe such storing of the entire quantity of water flowing in the stream and the use of it during a few hours in the evening when other manufacturers' plants were shut down, as unreasonable. Were this view taken, the town might be enjoined from the use of its mill pond for its

own best advantage, and the power which it might derive from the stream for its own use might thus be considerably reduced. If, on the other hand, the stream flow during the day were sufficient to take care of the needs of the mills, or if these mills had mill ponds of sufficient capacity to enable them to store during the dry season the entire twenty-four-hour flow of the stream, the town could doubtless avail itself of its mill pondage to the most advantageous limit."

I assume that where the character of the use has changed materially,— as in the case of an electric-light plant which has been established on a stream, and which wishes to use the water during hours only when the mills are virtually closed, as against the former use by a mill which operated twenty-four hours out of the day, — that the court would not hold that the newcomers would be entitled to so radically modify or change the regimen of the river for their own benefit as to seriously affect the operation of the privileges below them.

The question depends upon the size of the mill ponds above the privileges, as well as upon the quantity of water which is flowing in the stream. No court, I assume, would permit an electric-lighting company, for instance, to hold up all of the water during the daytime, to the disadvantage of the mill owners below who wanted to use it throughout the day, unless the mill owners below had mill ponds, which would make it possible for them to store the water, or the major portion of it, which was let down in a few hours during the night by the electric-lighting company.

It occurs to me to say just one word further, along the line to which Mr. Hale and Mr. Main just alluded, — the exact definition of terms. Mr. Main has just referred to the term " head." We recently had an interesting case in Maine, in which the word "head" was a matter of dispute. In this case a privilege had been sold, with the understanding that 17 feet of head were to be had at the privilege at a certain time, for the use of log drivers. The question then came as to how that head should be measured. It was the head from the bottom of the dam, was it not, Mr. Hale?

Mr. Hale. Yes, sir.

Mr. Metcalf. The experts on one side contended that, according to usage on lumber-driving streams, head was measured

at dams built for storing water for log sluicing and driving purposes from the sill of the dam or bottom of the waste gate, to the surface of the water above the dam, unless there was back water at the dam, and that the bottom of the dam was at this point, the structure below this point being in the nature of a sub-foundation. The experts for the other side contended that the bottom of the dam was the bottom of the lowest log in the structure, and they actually sent a diver down to get the elevation of the underside of the bottom log in the dam.

Of course, counsel for the plaintiffs took the view that, under the latter interpretation, out of 17 feet of head they would get something like 12 or 15 feet of mud, instead of water. It certainly was not water, nor was it available or convertible into power.

Mr. J. H. Cook.* I have listened with a great deal of interest to the remarks of the various gentlemen, and some of the things which were referred to had considerable interest for me. I suppose I can't talk of these things in their proper order, but I noticed that some one spoke — Mr. Barrows, I believe — about state regulation of water supplies, or control by the state of water supplies.

In the state of New Jersey at present, under a statute passed last winter, there is a commission appointed which claims to exercise control over all the waters of the state, and expects, according to the ideas of the people of the state, to build reservoirs and perhaps sell water for the supply of various towns in the state. Whether the state may sell water or not for that purpose of course has not been determined by any suit as yet.

The commissioners also intend, according to the terms of the bill, to cause all parties that divert water from the streams to pay to the state a certain amount per million gallons for water so diverted. The state, in fact, believes, or the legislature believes, that the state has absolute control over the water of the state.

I have heard, too, some of the speakers speak about compensating reservoirs. I know of a case — I did not suppose that they were very uncommon — in the state of New York. The Consolidated Water Company of Utica, N. Y., maintains a compensating reservoir on the upper waters of the West Canada Creek, and through agreement with the mill owners below, said company

* Hydraulic Engineer, Paterson, N. J.

passes out from this reservoir (which is on the upper Black Creek,—a tributary of West Canada Creek) the natural flow of the streams which flow into this reservoir, plus the amount the water company diverts at Hinckley, a point some miles down the river. They have only operated the thing about a year, and there has been some little friction already.

Somebody spoke about compensation in kind, and it made me think of a case in New Jersey, which perhaps may be familiar to some of the gentlemen now present. The water of the Pequannock River above Charlotteburg was taken by the city of Newark, which contracted with the East Jersey Water Company to build works for a water supply for Newark. On this river were some small streams upon which dams and reservoirs were built. After this work was completed, that is, after the storage reservoirs were built, the quantity of water that passed down the river into the intake reservoir was practically constant, changing the flow of the river, which had formerly been in the driest times two or three millions of gallons or less daily, and a very large quantity in times of freshet. A mill owner sued the company that built these works because he said they interfered with the natural flow of the stream, and the mill owner recovered damages; and presently, a few years afterwards, he brought another suit for interference with the flow of the stream since the time he recovered before, and again recovered damages. Then the water company got sick of that game and bought the property, which it was claimed was injured, although it appeared to some persons to have been benefited.

Mr. E. L. Grimes.* Mr. President, I have been very much interested in the discussion before the meeting, as we are at present trying out some of these cases in Troy, N. Y., and especially the one that has been referred to. One of the important points with us is in regard to compensation for the diversion of part of the water from the stream. A question which I think Mr. Main did not touch upon in regard to substituting a steam plant for the power diverted, is in regard to its location, distance from the railroad, or convenience in getting to the point. Now, the cost of substituting steam at a point that is very difficult to

* Chief Engineer, Troy, N. Y., Water Works.

get at would be much different from that at a point easily accessible and would, it seems to me, make quite a difference in the question.

Another question that is brought up is in regard to storage: A large mill owner upon the stream below our diverting dam has, above our diverting dam, quite a large storage reservoir. In certain seasons of the year, if he happens to be short of water, he lets this storage reservoir run down, and of course it benefits the parties between the storage reservoir and the owner's mill.

The point to decide is, What rights to the use of these stored waters have the mill owners who do not own the storage reservoir, or who depend entirely upon the flow as it is let down by the party who owns the storage reservoir? I understand that the mills intermediate do not pay any part of the maintenance of the storage reservoir, and I suppose they could not force the party to maintain the dam there or let the water down at certain times. Another question is, What value is that storage reservoir to the parties who do not own it?

We have also another system on which the riparian rights have been settled. It seems to me it would be interesting to know, or to have tabulated in some form which would be convenient for comparison, the awards of the damages in similar cases; and, in view of that, I have tabulated the cases relating to water powers that have been settled.

TABLE SHOWING AWARDS MADE IN 1903 FOR DAMAGE TO WATER POWERS BELOW DAM OF TOMHANNOCK RESERVOIR, TROY (N. Y.) WATER WORKS.

Drainage area above reservoir dam, 67 square miles.

	Remarks.	Total Award.	Award per Sq. Mile per Foot Fall.
About 1 mile below dam,	Old flax mill not used for several years, also old saw mill. Total fall, 18 ft.	$4 500.00	$3.75
About 1 mile below dam,	Farm area not given. Grist mill rather old. Total fall, 18 ft.	12 000.00	10.00
About 2 miles below dam,	Farms and water power undeveloped. Total fall, 150 ft.	22 000.00	2.20

	Remarks.	Total Award.	Award per Sq. Mile per Foot Fall.
About 3 miles below dam,	Undeveloped power and farm of 240 acres; 180 acres affected. Total fall, 40 ft.	16 000.00	5.97
		$54 500.00	$3.55

Mr. Hale. Mr. President, in regard to the use of the ten- and twenty-four-hour power, there is considerable attention being paid to that now, I think, by the various companies. When parties were attempting this year to obtain a charter for a dam at Reeds Ferry on the Merrimac River, the counsel for the Amoskeag Manufacturing Company was very insistent that there should be included in the charter the clause that no interference should be asked for in regard to the customary hours of running the mills at Manchester, or at any locality on the river above this point, as far as Lake Winnepesaukee.

They felt as though if this dam was to supply power twenty-four hours or ten hours, or whatever it might be, they might have some rights to insist on the natural flow of the stream, and they didn't know what might arise. These manufacturers wanted to protect themselves in that way, so they asked to have that clause put into the charter, which was agreed upon, as the probability of interfering with the mills above would be very remote.

I think in regard to the use of ten-hour and 24-hour power there is a case of Mr. Whitney at Winchendon in which Mr. Main and Mr. Coffin were consulted. I don't know how that was decided by the courts, but I think Mr. Main can tell us about that.

Mr. Main. I have the result of that case in mind. Mr. Whitney owned a large reservoir, and formerly had two water wheels, — one for his cotton mill and one for his machine shop,— and ran them both during the daytime. Several years ago the cotton mill ceased running, and the wheel in that mill stopped, and he used only the wheel in the shop. A few years ago he conceived the idea of using the wheel in the cotton mill for electric-lighting purposes, to light the town, and ran that during the night. He had a large reservoir to control the water and the owners below

him had very small ones and whatever water went through the cotton mill wheel at night got past their dams. They brought suit to make him stop using the water at night, and to require him to use it, they said, in the customary and ordinary manner, which was ten or twelve hours a day. Mr. Coffin and I found that approximately the same amount of water was used in the twelve hours of daytime as during the twelve hours of night-time, or about as the natural flow of the stream. Every one connected with the case for the mill owner thought he had a very good case, that the mill owners below could not make it necessary for him to use his dam and pond for their benefit, storing the night waters so that they could use it all in the daytime. We felt if he wanted to shut down his shop he could do so, and if he did the water would flow over his dam uniformly twenty-four hours a day.

The case was tried before a master, and the master found that Mr. Whitney must cease to use the water in the night, and use it only in the daytime. Mr. Whitney paid no attention to the finding of the master, and kept on running day and night. The court overruled the finding of the master, and found that Mr. Whitney had the right to use the water twenty-four hours in the day, provided that he used it as it came down to him and about as the natural flow of the stream. So that it turned out finally as we thought it ought to and as common sense would indicate, and everybody was happy except the mill owners below.

Mr. A. A. Reimer.* Mr. Chairman, that brings to my mind the question whether underground waters have been involved in any of these suits.

Chairman King. Can any one give us any information on this subject? Wasn't that suggested in the Newburyport case, Mr. Forbes?

Mr. Forbes. Mr. President, I don't know as I can answer this question just at this point. The matter of a ground water supply and the proportion it bears or the effect it has in regulating the flow of a stream, and particularly the flow during a dry season, is of course a very important one. It perhaps becomes less evident upon the larger streams; that is, the total effect is not so great; but where a small drainage area is considered the result

* Superintendent of Water Works, East Orange, N. J.

may be very noticeable, due perhaps to the fact that we do not know the extent of the drainage area, from a ground water point of view, with the accuracy with which we know the surface drainage area. So that unquestionably in many cases on small drainage basins the tributary ground area may be very much larger, thus accounting for the unusually high flow per square mile during the dry season. Possibly that is not just along the line that the speaker asked his question, but that may explain it somewhat.

Mr. Grimes. Perhaps it would be of interest to know about a little experience we had in a claim of this kind. A farmer put in a claim for diversion of the water, on the ground that it prevented percolation of the water through his land. His claim was for $5 000. In investigating the matter we found that he had something over five miles of tile drain laid to keep his land dry.

Chairman King. Will Mr. E. H. Foster, of New York, add something to this discussion?

Mr. Foster. I hadn't intended to say anything on this subject, Mr. President, but I have taken down a few notes on points that interested me in the papers that have just been read. One thing that impresses me about these cases is the very wide diversion between the estimate of value of the power as made by the mill owner and the value placed upon it by the prospective purchaser. About 20 to 1 seems to be the usual ratio. I have a case in mind where it was just about in that proportion, and I think Mr. Metcalf mentioned another. Much depends upon the circumstances surrounding the cases, the condition of plants, and so forth. An owner usually is able to see ahead that his water power is going to be condemned, and he lets his plant run down for three or four years, oftentimes until it is practically valueless at the time proceedings are instituted for making an appraisal, and it is very hard to get at the conditions as they existed at the time when the owner really first began to let his plant run down.

It seems to me that this general subject is of sufficient importance to the members of this Association to consider the appointment of a committee. Nearly all of these cases are between municipalities and mill owners. We represent largely muncipalities. The mill owners are largely represented by members

of the National Cotton Manufacturers' Association. The membership of these two associations is chiefly drawn from the same part of the country. Hence, the members are naturally familiar with the same problems from their respective viewpoints. Furthermore, the abundance of water power and the tendency toward manufacturing, has naturally led to a great many disputes on this subject in New England — probably more up to the present time than in any other part of this country.

Why would it not be a good plan to have appointed a committee to approach the cotton manufacturers, and intimate that they should appoint a committee, and have these committees act jointly to get up a set of rules or recommendations for estimating the value of water power diverted or appropriated for various purposes, and generally to embody the ideas presented in various papers before this Association, before the American Society of Mechanical Engineers and the American Society of Civil Engineers the valuable contributions by the author of the paper under discussion, the works of Frizell and various other writers on the subject, and boil it all down to a simple set of rules, which could be applied to a great many cases?

These cases are usually brought before a court and the court appoints a commission, which is generally a lay commission, and they hear the testimony. The result is a great waste of time and expense, which is not at all justified by the amount involved.

I really believe it would be conferring a benefit not only upon the mill owners,— the small mill owners especially,— but also upon municipalities that contemplate changes in their water system, to have some definite rules which could be regarded as more or less authoritative, and with this object in view, Mr. Chairman, I offer the following motion:

"That a committee be appointed by the Chair, to approach the National Cotton Manufacturers' Association, and invite them to appoint a committee, these committees to act as a joint committee to draw up a set of rules to govern the estimation of damages to water privileges by diversion."

Mr. Charles W. Sherman.* Mr. Chariman, it strikes me off-hand, without opportunity to give much consideration to the

* Civil Engineer, with Metcalf & Eddy, Boston, Mass.

matter, that this committee would have a very difficult problem, to say the least, and might find it impossible to get any coöperation from the Cotton Manufacturers' Association, in which case they would be thrown back on us with nothing done.

I am inclined to offer, as an amendment to Mr. Foster's motion, that the committee be appointed as he suggests, but instead of asking the cotton manufacturers to name this other committee to act with them, that our committee be appointed to consider the practicability of such a joint committee, and the possibility of its obtaining results that would be of value, and, if they see fit, to confer with the officers of the Cotton Manufacturers' Association as to their ideas and their practicability and possibility. It is hard to put that amendment in form without rewriting it.

Chairman King. It would be a substitute motion.

Mr. Metcalf. Mr. President, if I might make a suggestion, I should like to ask Mr. Sherman if he wouldn't include in his motion that this committee should collect data relating to awards for diversion of water and water power. It seems to me that the most valuable work this committee can do, or will be likely to accomplish, will be to accumulate specific data regarding awards in such cases. There have been quite a number of suits, on different streams, growing out of diversion, and the members of this Association, I think, can bring the data relating to awards together and put them into the hands of the committee, if the committee had power to accumulate them.

I question very seriously whether we will be able to get the coöperation of the Cotton Manufacturers' Association, and even if we do, whether it will be very effective. Of course the courts will finally have to pass upon the question of proper damages, and it seems to me it is a pretty big task to place upon any such committee, whereas data could be accumulated comparatively easily.

Chairman King. Perhaps it is not quite in order for us to dispose of that before it is amended in the motion. Is there anything further to be said in relation to the appointment of this committee, or any suggestions? If anybody has any suggestion to make it is a good time now to mention it.

Mr. Sherman offers the following substitute for Mr. Foster's motion:

"That a committee of five be appointed by the President to collect data relating to awards that have been made for damages resulting from the diversion of water; also to consider the practicability of joint action with the National Cotton Manufacturers' Association, or other organization of mill owners, leading to the formulating of standard rules and methods of computing or assessing damages for the diversion of water."

Does Mr. Foster accept this substitution?

Mr. Foster. I accept that.

Chairman King. Then, as Mr. Foster accepts this, this motion is now before you. Is there anything to be said on the motion?

The motion was put to vote and carried.

Chairman King. It is a vote and the motion is adopted.

THE SPRINGFIELD WATER WORKS.

BY ELBERT E. LOCHRIDGE, CHIEF ENGINEER, SPRINGFIELD WATER WORKS, SPRINGFIELD, MASS.

[*Presented September 11, 1907.*]

Mr. President and Members of the Association: In 1872, when the city took over from the Springfield Aqueduct Company the plant from which the water was supplied to the city, Springfield was situated in large part on the lower level along the river, on the plain upon which this hotel (the Cooley) is situated, and did not extend at that time to any considerable extent to the higher region. The population in 1870 was about 26 000, and the city had just reached the stage when more water was necessary. It was accordingly necessary, as one of the first acts of the city in its municipal rôle of water seller, to obtain a new water supply.

Several of the experts of the time were called and the various upland streams in the vicinity were studied, as was also the question of supply from the Connecticut River. At that time there was a report presented in favor of the Westfield Little River, the supply which the city is just now taking. This was found, however, to be too expensive for a city of 25 000 people. Cast-iron pipe was pretty high in those days, and there was a good deal of labor involved in getting the water out from the gorge.

As a consequence a scheme was developed by which it was planned to take water from several branches of Broad Brook, lying in the towns of Ludlow and Belchertown,— very largely in Ludlow, — and this was the water taken at that time. It was possible at a very reasonable cost to throw a couple of dams across the two small outlets of a large swamp and flow what is now known as the Ludlow reservoir, with an area of about 445 acres and with a possible capacity at high water of nearly 2 000 000 000 gallons. This, it was thought, would supply water for a considerable time. It had the added advantage that it stood some 160 feet, I believe, above the higher portion of the city, and although it was 12 miles

distant from Main Street, it was possible, with a 24-inch cement-lined pipe, to deliver a sufficient quantity of water under pressure to all parts of the city. Just at that time the city was growing eastward, or toward that supply.

That is, in general, the history of the taking of the Ludlow water. The supply from the first began to develop, in the summer time, unpleasant tastes and odors, and the records of the gate-keeper in those earlier days show that the water every year, from the very first summer, developed a green growth, which made the water very objectionable in appearance as well as for drinking purposes.

After several years, these disagreeable tastes and odors appearing each year for varying lengths of time,— some years for not more than a few weeks, and other years extending over two months or more,—it was found that the city would need more water, and in about 1890 or 1892,— I am not certain of the exact date,— another tributary was added to the Ludlow reservoir by means of a canal seven miles in length. It was hoped that this would not only furnish more water to the growing city, but would also cause circulation through the reservoir, improving the quality of the water and rendering the supply adequate for a longer period. This was done, and in fact from all I can learn from the records and from the testimony of the people who had to use the water before and since, it did make a considerable improvement, and the water was bad for a shorter portion of the year.

However, as time went on, the tastes and odors became more objectionable again, and in time the capacity of the supply was again inadequate, if we should consider the possibility of as dry years as had already been experienced, and the growing size of the city. In order to supply water during the time when the Ludlow reservoir was bad, three smaller ponds lying between the city and the Ludlow reservoir were taken, Chapin, Loon and Five Mile ponds. These ponds are in reality springs in a sandy soil, and they furnish a very clear, nice-appearing water. They are on a lower level than the main supply and consequently have to be pumped. These ponds cover, on an average, an area of about 30 acres each and have no feeding streams tributary to them, and but one of them has any outlet. It is, therefore, apparent that

they represent merely stored ground water, and their capacity is limited to that of the storage capacity of the surrounding sand. It has been found that the city could draw upon them for a little over 6 000 000 gallons per day during a period which will not exceed thirty or forty days, at the expiration of which the ground water of the ponds and the region about them would both be at a very low stage. They were particularly valuable in furnishing an exceptional quality of water at just the desired time, but their capacity was not quite sufficient to make up the total deficiency or to cover in extent of time the period of bad Ludlow water. Accordingly, the Jabish brook water was diverted about the reservoir, as is shown in the accompanying diagram, and was used directly from the small basin. While this was necessary in order to make up the necessary quantity of clear water, it was objectionable in that great care was necessary to prevent pollution, inasmuch as the water was used without having been held in storage even for a short time.

As the city continued to grow it was found that something would have to be done. A great many in the city did not attempt to use the water at all in the summer time; others filtered it, using a small house filter. This, of course, made an added item of expense to each consumer, and in general the quality was unsatisfactory. In addition to this was the fact that the time would soon come when there would not be water enough unless either additional storage should be obtained on the watershed or a new supply should be taken.

The history of the discussion over this problem is a long one, and there was a good deal of feeling on both sides, many feeling that Ludlow water, although not all it should be, could be made satisfactory, or at least usable, and that this should be done. On the other hand, those who looked into the future of the city thought that perhaps with the continued growth even more water would be necesssary, and that, on account of the necessity of large expenditure for the purification of Ludlow water, as well as the additional expense of further development, it would be better to go directly to some other supply.

After a number of attempts at securing legislation for various supplies, in the fall of 1905 all parties agreed upon a method of

procedure, which was adopted, and it has been carried into effect. That was, first, the construction at the Ludlow reservoir of a filter designed to remove the tastes and odors, or at least to help in the removal of the tastes and odors, during that season when it was objectionable, inasmuch as the water during the colder portion of the year was by no means unsatisfactory; and second, at the same time that this filter was ordered at the Ludlow reservoir it was voted to ask legislative permission to take for a new supply the waters of the Westfield Little River. In round numbers the total Ludlow sources have some 20 square miles of watershed, and Little River some 48 or 50. They are situated about equally distant from the city, the Ludlow source to the east and the Little River source to the west.

An added call for a new supply was made because of the insufficient height of the Ludlow reservoir. The hill section of the city has developed very rapidly, many higher points being now occupied than were at the time the Ludlow supply was taken, and as a consequence the need of more pressure was quite apparent. This, of course, could be obtained from a new supply, and probably obtained more cheaply, it was thought, than by raising the Ludlow supply to some greater height or by laying much larger mains.

This compromise plan was carried out successfully, the legislative permission for the taking of Little River was secured in April, 1906, a little over a year ago, and by July, 1906, the filter which was ordered in the November previous was in working order at the Ludlow reservoir.

Just a word as to this filter. The studies on the Ludlow water have covered a considerable period of time. In 1901 the state board of health, together with Mr. Percy M. Blake, operated experimental filters at the reservoir for about thirteen or fourteen months, and it was found that, with the exception of the summer period, the water could be treated very easily, but during the summer period the tastes and odors were never fully removed. Following this, in addition to many other experiments by the board of health, in 1903 Mr. S. M. Gray and Mr. G. W. Fuller were appointed by the Special Commission on Water Supply, who were to study this phase of the question, to look into the problem of a new supply. During that summer I was employed by these

engineers to study the Ludlow water, and during the Anabæna season twelve filters were operated. From no filter during that time was entirely satisfactory water secured. It was found that in the sand filters as operated the organic matter would clog the bed and an exceedingly disagreeable odor would be developed unless a rather high rate was maintained.

I will not go into these experiments, but following them the report was made that while the water could be purified, it would be by means of double filtration and with triple aëration, as it was found that it was the aërating of the water and the furnishing

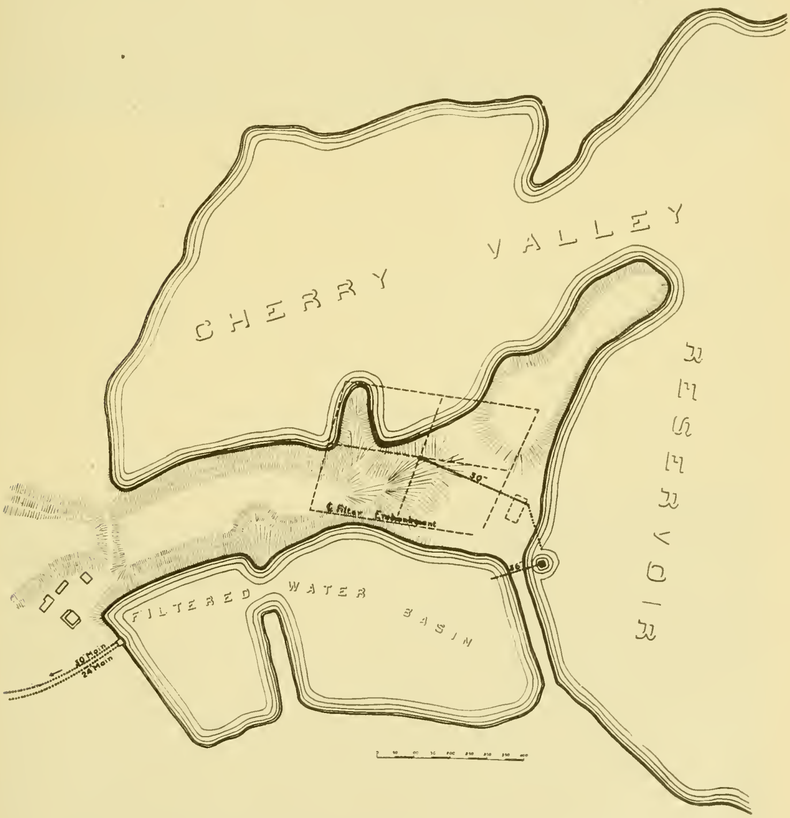


Fig. 1. General Plan showing Location of Ludlow Filters.

of sufficient oxygen to entirely remove the objectionable odors that was necessary to furnish an effluent of desirable quality.

As a consequence, when Mr. Allen Hazen was called upon to furnish a filter that should be both cheap and very efficacious in its action, he was confronted with a problem that I think he was hardly expected to solve.

This filter as designed was to be of sand, put in by analysis only and not by washing, directly from the sandbanks near the site of the filter. The water was to be pumped upon the beds and the usual height of the reservoir used for pressure in the city as heretofore. These filters cover practically four acres in extent and are of a depth of five feet of sand over tiled underdrains laid directly on the subgrade, with no concrete or other bottom. These are all connected into a main central drain, which carries the filtered water out to the clear water reservoir or basin, which, before the construction of the filter, was the controlling basin for the city. The filter was operated through the season of 1906 and furnished very satisfactory water. It is designed to give aëration before the water is delivered to the filter bed, so that even though the regular reservoir water is highly charged with organic matter and has but little dissolved oxygen, it will be thoroughly aërated. Following the filtration, it falls from the lateral drains into the central drain and again from the central drain into the basin, giving in each case an additional aëration following filtration. This was to rid it of any odors which would pass the filter, and also give a well-aërated water for use.

In addition to this the beds are operated intermittently, that is, for sixteen hours or longer if necessary to furnish the supply, but on an average of about sixteen hours each day, and then the beds are allowed to rest and to have air drawn through them so that the sand will become filled with air and in this way supply additional oxygen to the beds. In this the lesson, learned from the earlier experiments, that aëration was one of the essential features of the purification of this water, was made use of.

During the season of 1906 Mr. G. H. Shaw was in charge of the operation, and the results were quite satisfactory. However, at no time during that year did we have the amount of Anabæna (which is the bugbear of the reservoir) that we have had in a good

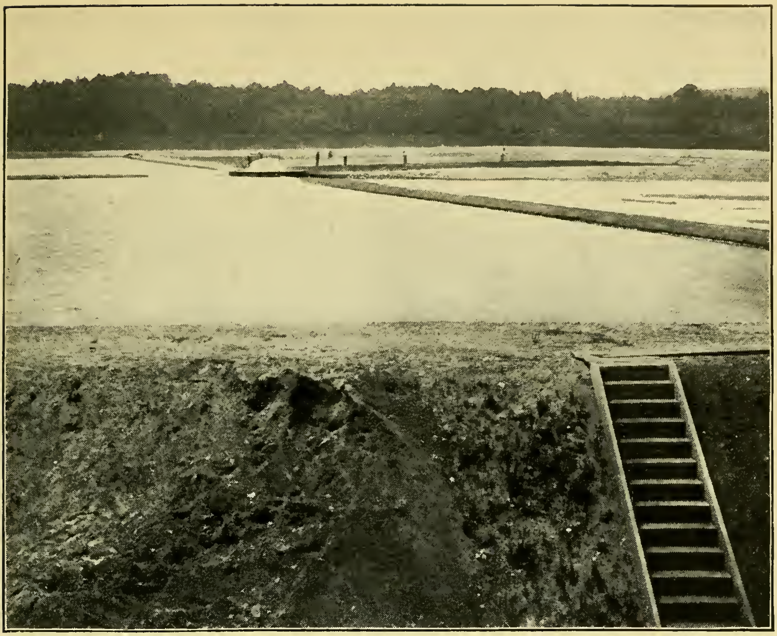


Fig 1. General View Ludlow Intermittent Filter, showing Arrangement. Aërator in center. Bed in distance in process of cleaning, remaining three beds in operation.

Fig. 2. Ludlow Intermittent Filter. Looking across one bed, showing sand embankment which separates beds, also aërator.

FIG. 1. LUDLOW INTERMITTENT FILTER. CENTRAL CONCRETE DRAIN AND WOODEN FLUME. POINT AT WHICH ALL FILTERED WATER LEAVES FILTERS. THE FLUME CARRIES THE WATER 100 FEET OUT OVER OPEN FILTERED WATER BASIN TO POINT THAT IS DEEP ENOUGH TO ALLOW FREE FALL OF EFFLUENT FOR FINAL AËRATION.

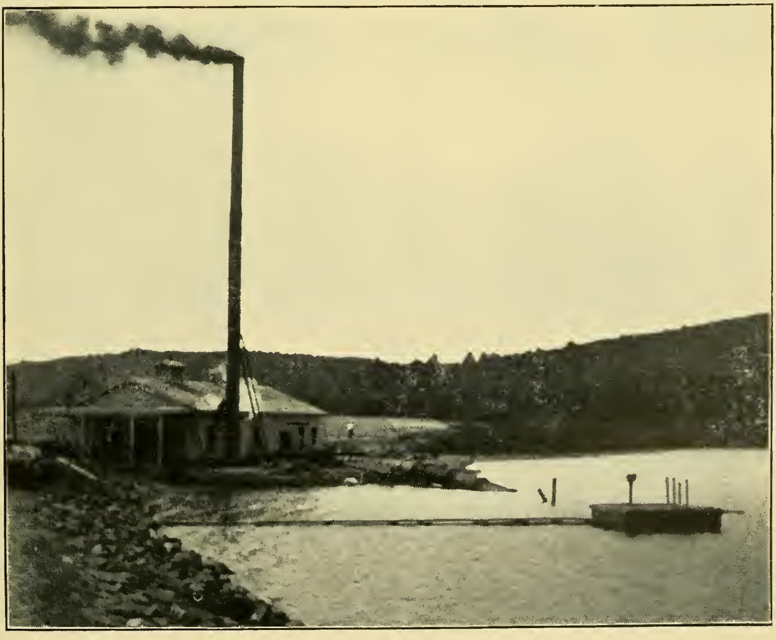


FIG. 2. LUDLOW INTERMITTENT FILTER PUMPING STATION AND LABORATORY. SHOWS 36″ INTAKE.

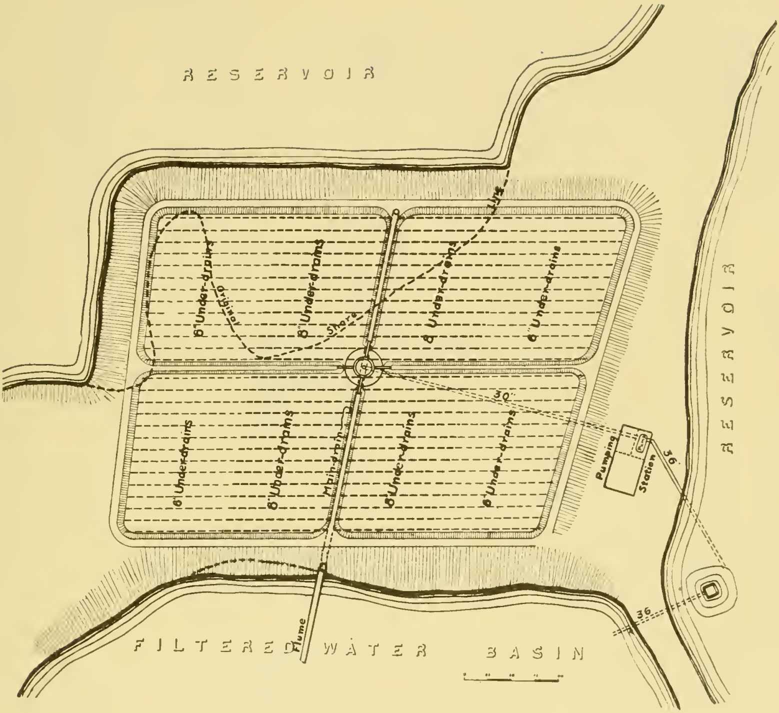


FIG. 2. PLAN OF LUDLOW FILTERS.

many seasons past, so we were afraid that perhaps we had not had representative results and that there would be seasons to come when the water could not be successfully handled. During the present season Mr. C. F. Story has operated the filter and has had some more difficult water to handle. The amount of Anabæna has been very much higher in the reservoir, and the amount of Uroglena at one time was much in excess of any we had before. The duration of the epidemic, however, was not as long as it has been in past years. However, at all times very satisfactory water has been produced. It has not always been entirely free from tastes and odors as it entered the basin, but it has been substantially free, and it has furnished a water which has been quite

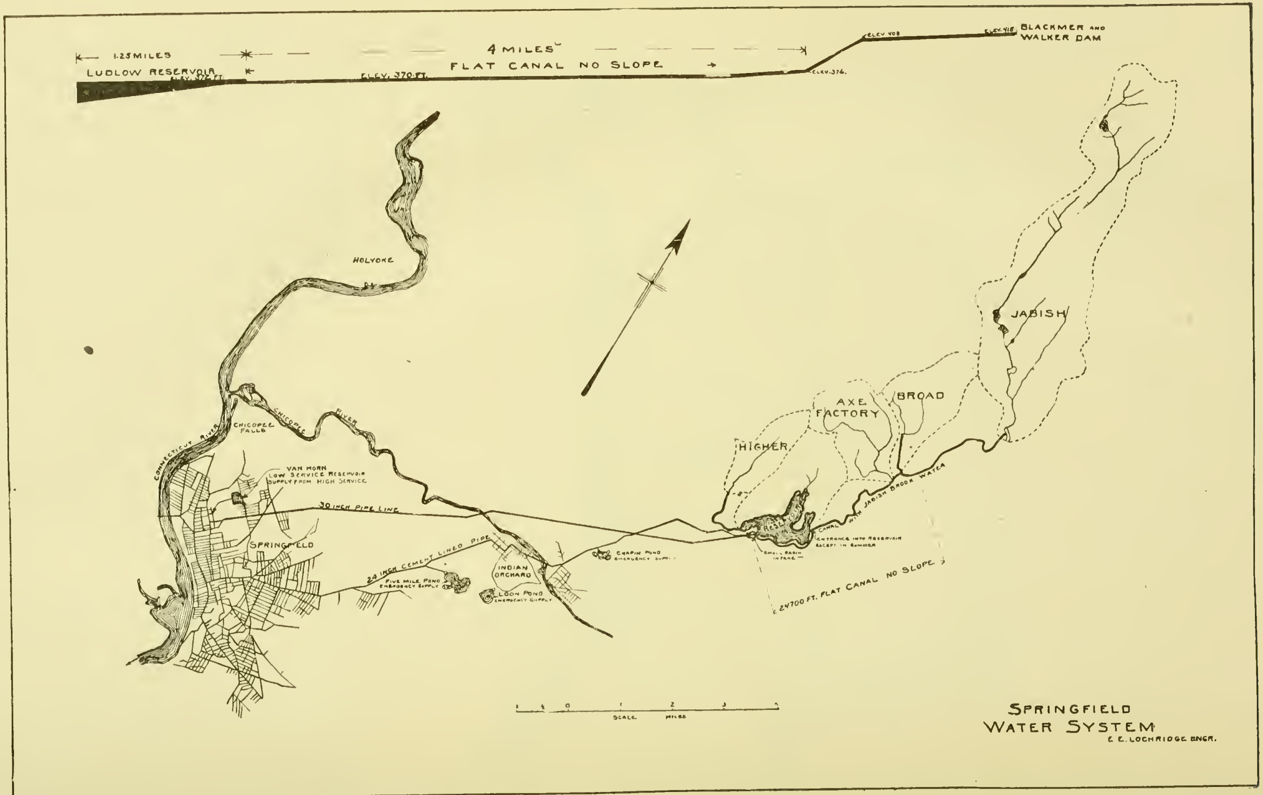


Fig. 3. Ludlow Supply, showing Watershed, Canal System, Pipe Lines and Location of Emergency Supplies.

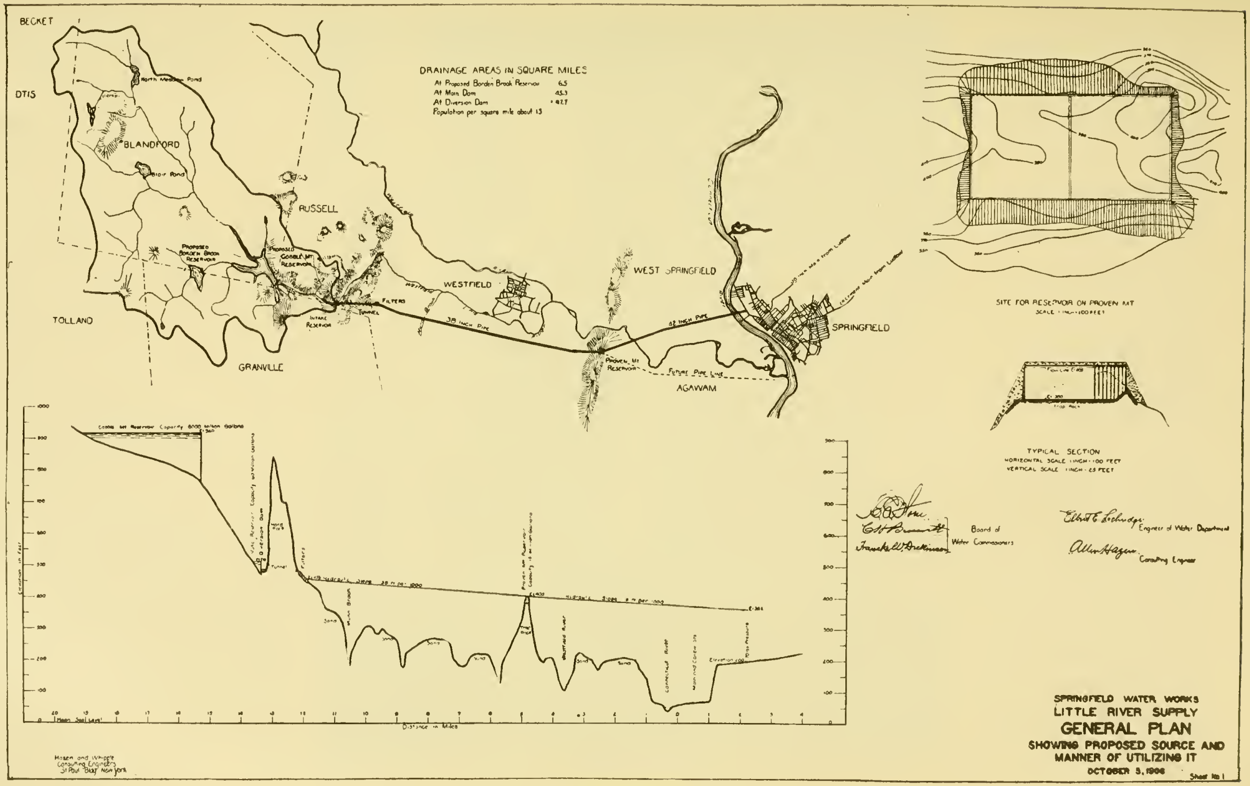


FIG. 4. LITTLE RIVER SUPPLY.

acceptable, I believe, to the consumers, and far more acceptable than any water we have had in any summer for a great many years.

With this filter thus established between seasons, and something done for the Ludlow water, the city was united in asking for a new supply, and with the acceptance by the city council of the Act authorizing the new supply, the work has been started to bring into the city, from an entirely separate source, in an exactly opposite direction, a supply which will be complete in every way.

It is planned to bring this in with a pressure of about 140 pounds on Main Street and about 70 in the hill section, which is 130 feet higher than Main Street.

This new supply has several features which are very desirable in a city system and which are not present in the old supply. It is taken from a very sparsely settled region; I believe with about 13 inhabitants per square mile. The region is mountainous, and the diversion of the water is from a gorge into which no road has ever been made, unless it was a logging road at one or two of the more accessible points, but a large portion of the gorge has never even been wooded on account of its steep nature. The sites for storage on the main stream are excellent. On the Ludlow system the water is all diverted by means of a long flat canal, and the main storage, the Ludlow reservoir, has practically no watershed of its own. While at present the requisite storage will be obtained from reservoirs on tributaries, a site is available which will supply enough water ultimately to supply the city until it shall become three or more times its present size. There are sites for filtration of the entire supply without loss of head or pressure in the city, as would have been necessary had the Ludlow supply been filtered without pumping. There is also within $4\frac{1}{4}$ miles of the city a site for a distributing reservoir.

At the present time, when an excessive draft is made on the present system, we have a very considerable loss in friction on two main pipes of between 11 and 12 miles in length; while with the new system we will have a reservoir which will be near enough, or at least much nearer than the old supply, so that a fire or other excessive draft may be maintained without great loss of pressure.

There will be several other features of the new supply, which is to be put in at an estimated cost of a little over $2 000 000. This

PLATE III.

LITTLE RIVER SUPPLY — GORGE SHOWING NATURE OF STREAM.

is to be one of the few supplies, in this region at least, which will be taken from a mountainous source and filtered before it is used, the filter to be constructed before any water is taken. Filters have been built for supplies which receive more or less sewage, but as far as can be determined, this supply receives no sewage whatever, and, with the sparsely settled country, very little pollution of any kind.

At the present time, storage will be provided on one of the tributaries to the stream, and in this storage it will be possible to secure something like 2 000 000 000 gallons of water, with an area of only about 190 acres, making a much deeper reservoir for the storage than in the present system. The diversion dam, for which, together with the tunnel, the contract has just been let, is to be of cyclopean masonry and is to rise about 50 feet above the bed of the stream. The tunnel, 4 530 feet in length, will bring the water through the mountains to the filter site, from which a steel pipe will be carried across a very open country with but little ledge, and across land that is very largely sand, to the distributing reservoir on Proven Mountain, where a sufficient quantity can be held in reserve to equalize the fluctuations in the demand for water in the city. An additional feature will be the Connecticut River crossing and the connection with the city's mains.

An additional problem which the city has had to meet is that of its piping in the city. The supply coming from the east was brought in first through the residential section, and the mains were lessened in size as they approached the Connecticut River. Bringing in the supply from the west will necessitate the connecting of these mains in some way that the pressure may not only be properly maintained, but water provided for the city of the future.

There is a large amount of old pipe in the streets, and there is a large part of the city which is not at present gridironed, that is, there are no connections through to the neighboring streets. For example, Main Street is supplied with a 16-inch pipe running the greater length of the street, while Water Street (the next street toward the river and the one adjoining the river) is not supplied with any high-service pipe at all, while the side business streets extending off from Main Street are supplied only with small pipes

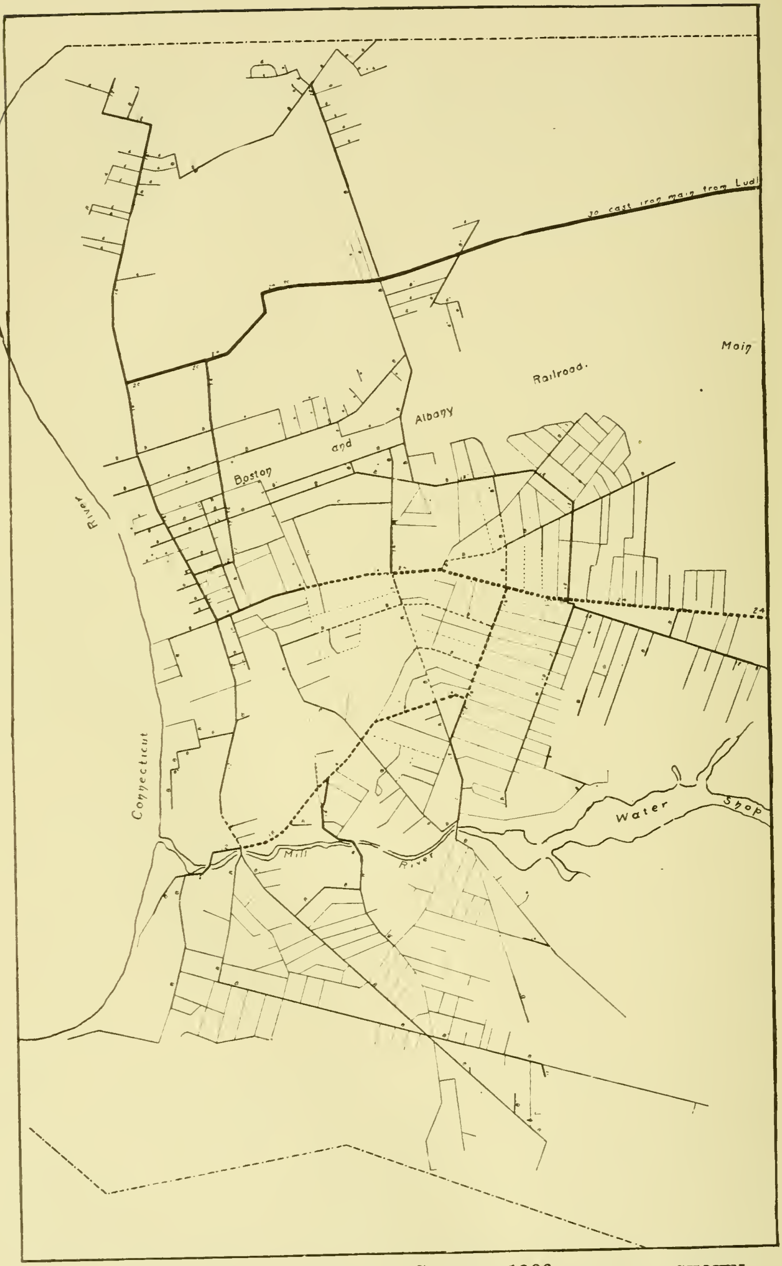


FIG. 5. SPRINGFIELD DISTRIBUTION SYSTEM, 1906, PIPE SIZES SHOWN RELATIVELY. DOTTED LINES INDICATE CEMENT-LINED PIPES.

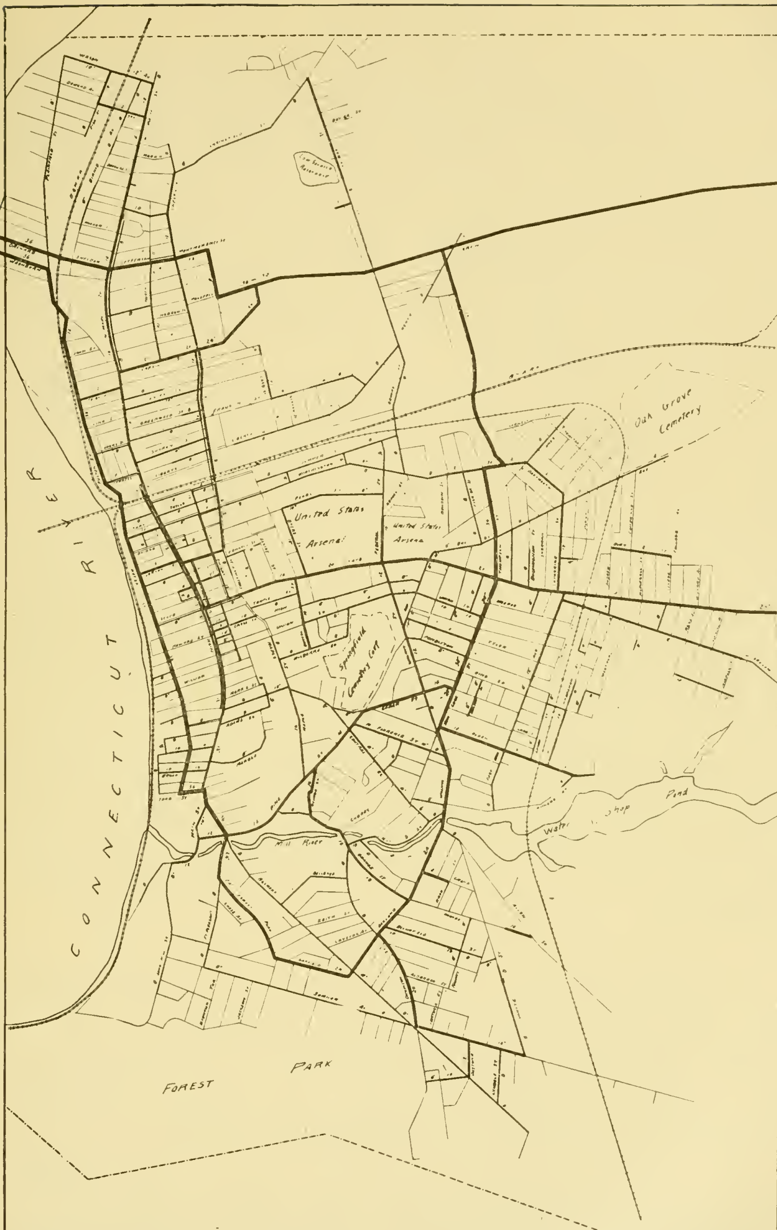


Fig. 6. Springfield Distribution System, showing circuit of large pipe around city. These changes now being made, about 20% having been completed in 1907.

which lead merely to dead ends at the end or middle of the block. It is necessary, therefore, in order to get the best system for the city, to reconstruct, or to bring in some manner, pipes to these streets, of sufficient size for fire purposes. This has been no small problem.

Mr. Hazen and Mr. John R. Freeman have both discussed this matter with us, and the matter was placed with Mr. Hazen, who secured Mr. R. D. Chase, who spent some months in studying the question of the proper fire service for the city and the proper distribution of the mains.

I will show you on the screen something of the problem which they had and the means which has been obtained of furnishing a good fire service to all parts of the city. (See Figs. 5 and 6.) This has been, or will be, accomplished by a belt main line about and through the main portions of the business and residential sections, a little over seven miles in length, which will be from 36 inches in diameter at the largest point to 24 inches, and at no point smaller. This will furnish the feeder which will draw water from either east or west, as may be needed, and deliver to any portion of the city the water under the full pressure, from which it can be taken into the smaller pipes and gridironed as may be needed.

This work of rebuilding the distribution system is well started, and this year considerably over $100 000 is being put into the improvement on the distribution system alone, largely in the starting of this circuit and in the extension and connection of the mains where it is necessary in order to provide for the new conditions.

DISCUSSION.

President Whitney. Mr. Lochridge's paper is now open for discussion. We should like to hear from Mr. Hazen.

Mr. Allen Hazen. Mr. President, ladies and gentlemen: I am glad to have an opportunity to add a few words to what Mr. Lochridge has said about the Springfield water works.

Mr. Lochridge has spoken of the Ludlow filter which was put in service at the beginning of last summer. I don't think it is quite fair to say that we built this filter. The filter was half built by nature before our work was started. It must have been some kind

foresight of Providence that put 100 000 yards or so of filter sand and gravel close to the Ludlow reservoir, and in fact partly in it, all ready to be tipped over with a steam shovel and made into a filter of the kind which you will see when you visit it. That was substantially the condition at Ludlow, and it was a novel condition, and we were able to utilize it fully for the benefit of the city.

There is another matter about the construction of this filter. It was built to a considerable extent in winter. The work was decided upon and authorized late in November. The filter was finished and put in service early in July following, before the worst summer condition of the water in the reservoir. And I want to say right here that the credit for building so large a filter in so short a time, and partly during winter months, is due to Mr. Lochridge and to Mr. Stone, the chairman of the Board of Water Commissioners. There was some steering from New York, but the pushing that enabled the filter to be built in so short a time was given by the two gentlemen named.

Mr. Lochridge has spoken of the long-continued experiments upon the treatment of the Ludlow water by Mr. Blake, and by Mr. Gray and Mr. Fuller, and by the state board of health, and he spoke of the fact that these experiments did not lead to a method of treatment that was at once economical and sufficient. It is true that the water was successfully purified in some of these experiments, but only by the use of double filtration under conditions which would have meant a very large expense for the construction and operation of a plant.

Ludlow water is pretty bad. I don't think that I need enlarge upon that. When we were at a legislative hearing some years ago, we told the committee that, as far as we knew, Springfield had the worst water supply of any considerable city in the state.

I speak of this to show that the problem which was considered in the experiments was a difficult one and a novel one. There were conditions that had not been met before, and it is not surprising that the first experiments did not lead to entire success with it.

And I wish to state at this time that while these experiments did not develop a sure and economical method for the complete purification of Ludlow water, they did serve to lay the foundation

for the method afterwards adopted; and I am glad of an opportunity to put this fact upon record to-day.

These experiments, in the first place, served to demonstrate that some methods and processes, which otherwise certainly would have been considered, would not succeed in the treatment of Ludlow water, and they served to give a good idea of the nature of the water and of how it acted under various conditions, and suggested the lines of modification of the treatments that were tested that would be most likely to prove successful.

And in studying the question some help was derived from the knowledge of sewage purification works. The organic matter that is most troublesome in this Ludlow water is chemically more or less like the organic matter in sewage, and it seems to be capable of being removed by the same methods. Sewage contains more organic matter than Ludlow water even at its worst, and a study of the methods of sewage purification which have successfully removed organic matters was of material aid in arriving at the design adopted at Ludlow.

The Ludlow filter as constructed had no direct precedent. It was to some extent an experiment. It was certain that it would make the water a good deal better, but it was not certain just how much better. The filter, therefore, was an experiment; but is differed from the experiments that went before in that it was conducted on a much larger scale and the effluent was put into the service pipes, and the people of Springfield were, therefore, made parties to the experiment and were able to judge of the results that were produced. And these results have greatly exceeded our expectations.

The Ludlow water is purified by this filter to such an extent that if quality were the only consideration, the people of Springfield would, I believe, be satisfied with water of the quality that they have received since the filter was put in operation. But the amount of water that can be drawn from Ludlow is limited. Springfield is growing rapidly and will certainly need much more water than is now used. In a wet year, or an average year, the Ludlow reservoir is able to maintain the supply that is now taken, but in a dry year it would be entirely unable to maintain that supply. Fortunately, in the last few years, since the consumption

has become so great, there has been no very dry year. Further, the pipes from Ludlow to the city are too small; the storage capacity is hardly enough; and if the supply were to be continued in use, new reservoirs, new filters, new pipe lines to the city, and, in fact, substantially a whole new plant would be required, as was conclusively shown by the report of Messrs. Gray and Fuller upon the Ludlow water. And this new plant would cost almost as much as the supply from a new source that is proposed.

Mr. Lochridge has told you about the Little River supply which has been authorized and upon which work is just being started. The design of this supply has presented some questions of the greatest interest. One of these is as to the most desirable pressure or elevation at which to deliver the water in Springfield.

Most of the Little River watershed has a great elevation. The main dam, which it is proposed to build sometime in the future, will have its flow-line some 900 feet above tide. It is physically possible to bring the Little River water into Springfield at any pressure that might be desired. It would certainly be possible physically to bring the water in with a pressure of 300 pounds per square inch, although it would cost a great deal of money to secure such a pressure.

The question to be determined was what pressure would be most desirable, all things considered, and taking into account the added expense involved in securing additional pressure. And there was also the question as to whether the city could best be served in two service districts, with high and low services, or whether it would be better to combine all in one system, with a moderate pressure in the higher parts and a rather high pressure in the lower parts of the city. Mr. Lochridge has already spoken of this problem of arranging the distribution.

The old part of the city along the river bank is but little elevated above it. Most of the larger and higher buildings of the city are in this low, flat area. Back of this area are bluffs of sand, with steep sides. The tops of the bluffs form a level plain of sand, extending back for miles, with here and there a valley cut by a stream or a rise of moderate elevation above the general level. On this sand plain the city has grown rapidly in the last years, and the greatest growth is now upon it.

There was a good deal to be said in favor of the proposition to have two separate services, a high service for the elevated plain, and a low service for the river bottom; but the arrangement of the piping could be more conveniently and cheaply made for a single system, and the single system unquestionably provided best for the concentration of large quantities of water wherever it might be needed in the case of an extended fire or conflagration.

These questions were taken up with Mr. John R. Freeman, and after studies were made of different projects and of the possibilities of reservoir sites, he advised us to adopt one system for the whole city.

The single system is cheaper, simpler, and, as he thinks and as we think, it is better. This single system which is adopted means that a pressure of 130 to 140 pounds will be carried on the river bottom, and that a pressure of 70 to 80 pounds will be carried on the sand plain immediately on top of the bluff and the center of the city in the immediate neighborhood of the United States Armory, and that somewhat smaller pressures will be carried in the highest and most remote points of the city.

The site selected for the distributing reservoir is on Proven Mountain and is the only site within a corresponding distance of the city at sufficient elevation to maintain this pressure. It is very fortunate that it was possible to locate the new works so as to take advantage of this distributing reservoir site, and it was also very fortunate that a saddle was found at the right elevation in the ridge, which usually is of trap rock and too narrow and steep to afford a satisfactory site. The site selected is sufficient not only for the construction of the reservoir which is now proposed, but will also serve for an addition of another part of equal size when the growth of the city makes it desirable.

The proposed Little River works are designed all the way through with reference to extension. A 15 000 000-gallon plant is now being built, but everything is designed for an ultimate extension of double, or more than double, that capacity.

The Little River water is to be filtered, although it comes from a hilly and almost mountainous watershed that has but little population upon it. Filtering the water adds something like $300 000 to the cost of the project. It insures the delivery of a

water of greater attractiveness from a physical standpoint, and it largely eliminates possible danger of disease which might come from accidental contamination of the sources.

The filtered water is to be stored in a covered reservoir, that is to say, in the distribution reservoir on Proven Mountain. Covering this reservoir is also something of a novelty for a supply of this character. The cover is provided to keep out the light and to prevent the growth of organisms in the reservoir, which growths tend to reduce the quality of the water.

At Ludlow, as you will see on Friday when you visit the present filter, the effluent is stored in an open reservoir, called the Little Basin, which is a part of the Ludlow reservoir cut off by an embankment; and in that little basin you will see that there are growths of organisms, and the water flowing from it to the city is not of quite as good quality as the water that comes from the filters. This condition of storage of effluent in an open reservoir, with a consequent deterioration in quality, was tolerated in the Ludlow design because the whole purification plant is for temporary service, and it was, therefore, wise to take some chances on deterioration rather than spend the large additional sum required to prevent it, as we should wish to do if it was for permanent service. But in the Little River supply we propose to keep all filtered water in the dark and bring it into Springfield in just as good condition as it leaves the filters, and so attractive and wholesome that there will not be any excuse for the spring water business to exist.

Springfield started with the worst water supply of any considerable city in the state. It is the ambition of the water board and of Mr. Lochridge, and of the speaker, to carry out the works now authorized in such a way as to provide Springfield with the best water supply of any considerable city in the state.

Mr. Lochridge. Mr. President, I don't know as there is any way of describing the water when it is impregnated with Anabæna unless you have seen it, and you have got to multiply it after it is described. I will let each of you do that.

The reservoir, covering something over 400 acres, is, during the summer, filled with small, hairlike substances or filaments, which are in reality the filaments of this Anabæna. Looked at under a

microscope, they are made up of small beads, and they are each of them about two thousandths of an inch in diameter, although the filament may be half an inch long.

The water is entirely filled with this to such an extent that if you should put your hand below the surface, holding it straight below the surface, it could not be seen at all at a depth of three inches. It is frequently that way, and I haven't a doubt that some of the people who are here, that I know have lived here a good many years, could tell you they had seen it in the pipes almost as bad, but we always tell them that the water they get in the pipes is diluted, that some of it runs around the reservoir from the brook. That is one way of describing it.

Following this period, and it isn't very bad at this time,— you can drink it, it isn't very bad yet,— they begin to die and then you begin to get your tastes and odors. The oil sacs are liberated, and it was in this that one of the big problems of the filtration came.

The Anabæna in its fresh stage is handled by the filter quite easily, but when it begins to die, and you have this organic matter in this enormous quantity, in some state of decomposition, you have a form that we choose to refer to as secondary odors, and it is these secondary odors which are, to a certain extent, developed in the pipes in the passage for some 10 or 12 miles in the dark. That is the odor which it is hard to remove by filtration; in fact, the filter won't do it; it has got to be aërated following the filtration.

During 1903, when I was at the reservoir, this stage I have described lasted from the first day of August through till some time in October; that is, over two months — all of August and September. When the cold weather comes on, it coagulates; that brings it up. And the Anabæna has, in addition to the chlorophyl,— the green coloring which we know in all plants,— cyanophyl, which is a blue coloring matter. These colors separate, and the whole mass comes up and covers something like 40 or 50 acres of the reservoir. It usually gathers together in some such mass. I have seen it a number of times. That mass is from three to four inches thick, and you can put your hand in and lift out quite a good-sized cake of it. But you have got to hold it pretty carefully. It will go through rather a fine mesh. It is in

blue and green streaks. After a person visits the reservoir and looks at that, he goes home and doesn't drink the water for a year. I have had several tell me that that is exactly what they did. In reality this mass has all come out of the water before they get it in the pipes. It is not in such a bad state, but the breaking up of this matter makes a taste and odor which are decidedly objectionable, and of the worst form for the treatment by filtration and aëration.

At the time of this formation of the jelly-like mass, which always follows the period of the excessive Anabæna count, a stone the size of your fist can be rolled out upon it and it will stay there. I have seen it stay there three or four days, if you will believe it, although you are all welcome not to, as few do unless they see the reservoir during one of its very bad stages.

Mr. Weston. I should like to ask Mr. Lochridge what rate of filtration is usually employed at the Ludlow filter.

Mr. Lochridge. There are four beds of substantially an acre in extent each. We get all the water we want for each day out of that. The use of the city is between ten and twelve million gallons a day. The fact that there is no concrete bottom to the filter means that there is a considerable loss. Perhaps 40 per cent. of that loss makes its way into the basin and isn't a loss, but it doesn't go out through the underdrains. The other 60 per cent., or perhaps more, goes back into the reservoir and is not lost to the system, but is lost to the filtered water basin. And Mr. Story, who has operated the filter this year, and who is present, told me this morning that one fourth of the total amount pumped went through below the underdrains. Three beds are always operated, or practically always. I will try to have it arranged to have one bed off, so that you may see how it is cleaned on Friday when you go out to Ludlow. I don't know whether there will be mud enough on those beds or not, but you will see something about what we have done.

President Whitney. I should like to ask Mr. Hazen if this idea of filtering the new supply was the ultimate result of thinking it over, or was it intended at the start?

Mr. Hazen. I don't know as I quite get your question, Mr. President.

PRESIDENT WHITNEY. What I wanted to say was, did you at the start intend to filter this new supply, or was it something which came into the final making of the plans?

MR. HAZEN. Oh, we intended to filter it at the start.

PRESIDENT WHITNEY. Was it considered a necessity?

MR. HAZEN. No, sir; it was regarded as desirable.

MR. MURRAY FORBES. How did you arrive at the conclusion to filter instead of sanitating or purchasing some of the watershed?

MR. HAZEN. We thought we could do a lot more for the money.

PRESIDENT WHITNEY. I wonder if any of the other members present have had experience with this same organism, the Anabæna, — experiences similar to those described by Mr. Lochridge.

MR. HAZEN. I think Mr. Weston has had experience in treating such organisms.

MR. ROBERT SPURR WESTON.* Mr. President, there is not very much to be said beyond a very brief account of some experiments made for the Athol Water Department last summer. The water supply of Athol comes from two impounding reservoirs, one of which, the Phillipston reservoir, is nearly as bad as Ludlow, and is subject to growths of Anabæna, Aphanizomenon, and other organisms. The water commission authorized experiments last summer, and accordingly a small trickling filter of coarse, crushed stone and a small intermittent sand filter were built and operated with the coöperation of the Massachusetts State Board of Health. Analyses were made under the direction of the speaker. These devices were in operation from the first of September to the end of the algæ season, 1906. These devices were practically the trickling filter and the intermittent filter such as are used for sewage disposal, and were operated in a similar manner.

The water in the Phillipston reservoir is deficient in oxygen and abounds in organic matter, and it was thought that the logical remedy for the bad condition of the water would be the removal of the organisms by some method of filtration and the removal, produced by aëration or some other means, of the odor. It was also believed that on account of the deficiency of oxygen continuous filtration would not suffice. The trickling filter was operated at a rate of 2 000 000 gallons per acre per day, water

* Sanitary Expert, Boston, Mass.

being applied continuously. The intermittent sand filter was dosed three or four times a day, and the rate of filtration varied between 200 000 and 1 000 000 gallons per acre per day. The intermittent filter was operated without aëration. It was desired to obtain data for organism removal and aëration independently of one another.

After the first week the effluent from the intermittent filter was nearly colorless and free from turbidity. It had a musty odor, however, but it must be remembered that this filter was purposely operated without aëration.

The effluent from the trickling filter as it came was almost completely free from odor, but it was not free from organisms. Consequently, after a short time, the aërated water again possessed an objectionable odor. Briefly stated, the experiments proved that a thorough aëration would remove the odor from the water and that intermittent filtration would remove most of the color and all the turbidity. The results of operation are as follows:

Removal of Organisms.

Source.	Average Number of Organisms per c. c.	Percentage Removed.
Phillipston Reservoir	5 637	0
Filter No. 1	2	99.96
Filter No. 2	3 996	30

The almost complete removal of the organisms by Filter No. 1 is noteworthy.

Removal of Odor. The trickling filter No. 2 removed 45 per cent. of the odor, as shown after the samples had been received in the laboratory. Filter No. 1 removed only 10 per cent.

Removal of Color.

Source.	Average Color.	Percentage Removed.
Phillipston Reservoir	0.60	0
Filter No. 1	0.06	90
Filter No. 2	0.54	10

Removal of Organic Matter as Shown by Nitrogen as Free Ammonia. Parts per 100 000.

Source.	Average Free Ammonia.	Percentage Removed.
Phillipston Reservoir	0.0100	0
Filter No. 1	0.0021	79
Filter No. 2	0.0131	—31 (apparent increase)

REMOVAL OF ORGANIC MATTER AS SHOWN BY THE TOTAL NITROGEN AS ALBUMINOID AMMONIA. PARTS PER 100 000.

Source.	Average Albuminoid Ammonia.	Percentage Removed.
Phillipston Reservoir	0.0673	0
Filter No. 1	0.0136	80
Filter No. 2	0.0587	13

The logical conclusion from these experiments was that the organisms, and to a great extent their food material, could be removed by intermittent filtration, but that filtration without aëration did not suffice. The experiments also showed that the rate at which the intermittent filter operated, less than 1 000 000 gallons per acre per day, could be increased considerably and still furnish an agreeable effluent.

MR. ROBERT J. THOMAS.* Mr. President, Mr. Lochridge says that one filtration or two filtrations and aëration will not remove the Anabæna, or the trouble from the Anabæna. I would like to ask his opinion of spreading that out on such sand or gravel on a natural slope, perhaps 30 or 40 feet above, and falling into it, three, four, or five hundred feet away from the filtration gallery or collecting gallery; let it filter through this natural sand or gravel into this gallery. Would that remove it, do you think?

MR. LOCHRIDGE. I wouldn't be able to say. We get an immense amount of material, of muck or mud or whatever it is, on top of the sand. If you had sand of just the right kind and made a gravel filter, I should think it would. But we find that our sand very soon becomes used up, covered up, and there is no question but what its life would be short were it not possible to take off the Anabæna which is taken out. And, in fact, every four to ten days during the season, according to the amount of Anabæna and other conditions of the water, it is necessary to take off a layer of the sand, which is practically watertight.

MR. THOMAS. Mr. President, in removing the Anabæna, if I understand, he didn't get satisfactory results with the two filtrations and the aëration.

MR. LOCHRIDGE. That was true in the 1903 experiments which were made; yes, sir.

* Superintendent of Water Works, Lowell, Mass.

Mr. Thomas. Not all of it was removed; some remained in the water?

Mr. Lochridge. Only at the time of the worst water.

Mr. Weston. Mr. President, if I might take the liberty of replying to Mr. Thomas's question, I would say that the essential thing in a filter for the removal of the excessive odor due to organisms is to periodically drain the sand layer and give it fresh air. There is not enough dissolved oxygen in water of the class treated to burn up the large amounts of organic matter which are being stored in the filter day after day. Consequently, the water must receive a treatment more like that given sewage where one doses the filter and then gives it a day's rest in order that the bacteria which effect the destruction of the organic matter may be revivified by the aëration of the bed; it is well known to all that the bacteria which effect the destruction of organic matter, whether in sewage or water, not only live upon the organic matter, but require oxygen as well.

I would like, Mr. President, to ask if the copper sulphate treatment has been considered in Springfield. I would like to ask Mr. Hazen if he has considered it in other cases similar to those outside of Massachusetts.

Mr. Hazen. I suggested the use of copper sulphate, or at least endorsed its use for the Ludlow water, but the state board of health was against us on that point, and as we had to have their coöperation and support in other matters, that matter was not pressed. In other cases I have approved of the use of copper sulphate, where Anabæna has been troublesome, and from it considerable relief has been experienced; but in no case has good clean water been secured by this treatment of the water, corresponding to that which can be obtained by proper filtration and aëration.

Mr. M. F. Collins.* Mr. President, I should like to ask Mr. Lochridge what effect the size of the sand has on the contents of the filter.

Mr. Lochridge. The sand was analyzed and put in by analysis. That is, one or two men spent their whole time watching the sand bed as it went in. We tried to get sand of 0.35 of a milli-

*Superintendent of Water Works, Lawrence, Mass.

meter. We did get that size for a considerable part of it. I think, however, that while we could get as high as 0.44 at times, or a little higher, that a statement of size of between 0.30 and 0.35 would be about right for all of it, considering the way it was mixed.

President Whitney. I should like to ask Mr. Lochridge how uniform that sand runs.

Mr. Lochridge. No uniformity at all; that is, it went in as it was found. The larger stones were eliminated where we could and put in a bucket. If we picked up about a yard, and got but few in it, we let them stay. We raked them off from the top,— that is practically all, — and made a uniform height.

Mr. Codd. I should like to ask Mr. Lochridge if the filters handle the Uroglena as effectually as the Anabæna.

Mr. Lochridge. They certainly do some pretty good work on it. I think we had something like 30 000 per cubic centimeter for a while. I don't know how it would hold out for a long period, but we certainly got very good water. It does not handle it as easily; the filters clog up much quicker. Possibly it would require larger filters, and probably it would require greater aëration, but it did handle the water that we had.

President Whitney. We should like to hear from Mr. George A. Johnson on this subject.

Mr. George A. Johnson.* Filtration problems which have to do with the removal of tastes and odors from water are never very easy of solution. Here at Springfield, however, the promises are strong that this most disagreeable and vexatious phase of the question is being successfully overcome, and the manner in which this is being brought about reflects great credit upon the engineer of the department and his advisers.

In his travels of last year one of the most striking examples of the difficulties to be encountered by water-works men in tropical countries came to the speaker's attention in going over the situation at Singapore, Straits Settlements. Here the supply is derived from small jungle streams draining about 25 square miles of area, much of which is swampy in nature. The water is highly colored as received at the storage reservoir and frequently possesses a strong fishy odor, and the taste is often highly objec-

* Principal Assistant Engineer with Hering & Fuller, New York City.

tionable. The storage reservoir has a capacity of about 1 000 000-000 gallons, corresponding roughly to a storage of 200 days. This long period of storage apparently does not affect the character of the water to any material extent, and on walking around and closely examining the banks of this reservoir, the speaker was unable to detect any signs of algal growth.

The water is filtered before consumption through slow sand filters which, when operated in the usual manner, were not successful in effecting a diminution in the objectionable tastes and odors. In view of this fact the municipal engineer adopted a scheme of operation whereby the beds were allowed to rest empty for a period of about twelve hours in every one or two weeks, maintaining a rate of filtration when in operation of about 1 000 000 gallons per acre daily. According to statements made by those in charge of the works and citizens of Singapore, this intermittent method of operation has proved successful in this case in the more satisfactory treatment of the Singapore water. At the time of the speaker's visit, however, although this method of operation was then in use, the filtered water possessed a strong odor and was quite objectionable to the taste.

With reference to rainfall statistics, some interesting data were found at Calcutta, where, although the annual rainfall amounts to only about 60 inches, as much as 40 inches has fallen in a single week, and quite recent records show that there have been daily rainfalls amounting to as much as 10 to 15 inches.

Few people realize the stupendous progress which is being made by the Japanese in water filtration matters. Although the first public water supply was inaugurated at Tokyo in the year 1600, it was not until 1885 that the first modern system of water-works, including slow sand filters, was put under construction at Yokohama.

At the present time there are 13 cities in Japan, with an aggregate population of 4 000 000, which are supplied with filtered water. In considering the comparative populations of Japan and America, it is seen that Japan practically stands on a par with America so far as her progress in this line of municipal sanitary work is concerned.

The piping systems are quite complete and about one third of

all the service lines are metered. There is a fire hydrant to about every 50 houses. The total cost of all Japanese water works to date is about $11 500 000, or $115 000 per million gallons, or $2.80 per capita.

Very little water is wasted in Japan, as shown by the fact that the average water consumption amounts to no more than 25 gallons per capita per day.

President Whitney. I wonder if Mr. Codd would give us his experience with filters.

Mr. Wm. F. Codd.* Well, I don't know that I can say much about it. We have the Anabæna occasionally, but we haven't done anything with it except avoid it by getting ground water. We haven't been able to filter it successfully. At times it shows very thick in the pond; looks as though one had put valvoline oil into the water. It has about that dark-green appearance. I don't think I can tell you anything about filtering it.

President Whitney. I imagine that very few departments are so situated that they can avoid trouble as Mr. Codd does, by using the ground water. We would like to hear the views of Mr. Story, the operator of the filter in Springfield — your views in a general way, Mr. Story, in regard to the operation of the plant.

Mr. C. F. Story.† Mr. President, I don't know that I can add anything to what Mr. Lochridge has said, but I would be very glad to answer any questions along the line of operation and methods. I think perhaps I can tell the members more when they make the trip on Friday.

Mr. Hazen. Tell them about the dissolved oxygen in the effluent.

Mr. Story. I make the practice of taking my samples of dissolved oxygen directly from the small underdrains, so as to get a sample of the water after it has passed through the bed and before it has had any aëration. On a bed that is clean and running at a good rate the dissolved oxygen is always high, and as the bed grows dirtier it drops. In the worst periods of the reservoir water the dissolved oxygen dropped to a point as low as 35 per cent. saturation. At such times the filter gave an effluent which was

* Superintendent of Water Works, Nantucket, Mass.
† Assistant Engineer, Springfield Water Works.

as high as 80 per cent. saturation. I always watch the underdrains closely, and it is my endeavor to shut off a bed, if possible, when the dissolved oxygen in the effluent has dropped to a point less than 70 per cent. saturation. When we find the dissolved oxygen is being reduced in the filtered water, we remove the water from the filter, scrape the bed, and clean it out. In that way the water is always good.

Mr. Collins. I should like to ask Mr. Story a question. I understand that the operation of this is about sixteen hours a day. I want to know what his rate of filtration is to aërate the sand.

Mr. Story. I wouldn't want to say off-hand, but figuring on the sixteen hours a day, it would be considerably over 3 000 000.

Prof. Leonard P. Kinnicutt.* What limit do you set to dissolved oxygen before you change the filter, — before taking it off?

Mr. Story. I think I can best express that by saying that we started in June at the reservoir with the dissolved oxygen 90 per cent. saturation, and it ran down during the worst periods to as low as 35 per cent. saturation. The filters when working well always give between 75 and 90 per cent., and I usually took the filter off when it dropped below 70 per cent. saturation.

*Worcester Polytechnic Institute, Worcester, Mass.

PROCEEDINGS.

JUNE 26, 1907.

The annual " field day " of the Association was devoted to an excursion to Gloucester, Mass., by steamer *Cape Ann;* a shore dinner, followed by a trolley ride around Cape Ann; and a return to Boston by train.

No business meeting of the Association was held.

TWENTY-SIXTH ANNUAL CONVENTION, SPRINGFIELD, MASS., SEPTEMBER 11, 12, AND 13, 1907.

The twenty-sixth annual convention of the New England Water Works Association was held at Springfield, Mass., on Wednesday, Thursday, and Friday, September 11, 12, and 13, 1907, at the Cooley Hotel.

The following members and guests were in attendance:

HONORARY MEMBERS.

F. W. Shepperd. — 1.

MEMBERS.

S. A. Agnew, Kenneth Allen, J. M. Anderson, C. H. Baldwin, L. M. Bancroft, F. A. Barbour, H. K. Barrows, G. W. Batchelder, W. U. C. Baton, J. E. Beals, J. F. Bigelow, F. E. Bisbee, G. H. Bishop, J. W. Blackmer, E. M. Blake, C. A. Bogardus, James Burnie, C. H. Campbell, L. G. Carleton, T. J. Carmody, J. C. Chase, J. H. Child, H. W. Clark, W. F. Codd, M. F. Collins, W. R. Conard, J. H. Cook, P. C. Denehy, John Doyle, M. J. Doyle, E. D. Eldredge, E. A. Ellsworth, L. N. Farnum, J. A. Fitch, A. A. Fobes, A. P. Folwell, A. B. Farnham, Murray Forbes, E. H. Foster, A. N. French, F. L. Fuller, S. DeM. Gage, F. J. Gifford, D. H. Gilderson, A. S. Glover, X. H. Goodnough, E. L. Grimes, P. T. W. Hale, R. A. Hale, F. E. Hall, J. C. Hammond, Jr., J. D. Hardy, A. R. Hathaway, W. C. Hawley, N. W. Hayden, Allen Hazen, A. B. Hill, G. A. Johnson, W. E. Johnson, Willard Kent, A. C. King, G. A. King, H. M. King, L. P. Kinnicutt, J. J. Kirkpatrick, E. E. Lochridge, F. H. Luce, S. H. McKenzie, T. H. McKenzie, Hugh McLean, H. B. Machen, C. T. Main, A. E. Martin, D. H. Maury, John Mayo, A. S. Merrill, F. E. Merrill, Leonard Metcalf, H. A. Miller, F. F. Moore, T. W. Norcross, O. A. Parks, Washington Paulison, E. M. Peck, E. L. Peene, E. B. Phelps, A. E. Pickup, A. A. Reimer, W. H.

Richards, H. W. Sanderson, Charles Saville, E. M. Shedd, C. W. Sherman, M. A. Sinclair, H. O. Smith, P. S. Smith, H. T. Sparks, J. F. Sprenkel, G. A. Stacy, W. H. Sutherland, C. F. Story, W. F. Sullivan, R. J. Thomas, W. H. Thomas, J. L. Tighe, J. A. Tilden, D. N. Tower, C. A. Townsend, W. H. Vaughn, J. H. Walsh, C. S. Warde, R. S. Weston, J. C. Whitney, C.-E. A. Winslow, G. E. Winslow, I. S. Wood, Walter Wood, C. L. Wooding, L. C. Wright. — 119.

Associates.

Anderson Coupling Company, by Charles E. Pratt; Roy S. Barker; Harold L. Bond Company, by F. M. Bates; Builders Iron Foundry, by A. C. Coulters; Central Foundry Company, by C. F. Blunt; Chapman Valve Manufacturing Company, by Edward F. Hughes, R. W. Wight, W. V. Threlfall, and Edward L. Ross; The Fairbanks Company, by F. A. Leavitt and C. A. Sleeper; Hart Packing Company, by Horace Hart; Hays Manufacturing Company, by T. F. Nagle; Hersey Manufacturing Company, by Albert S. Glover, J. A. Tilden, W. A. Hersey, and William C. Sherwood; International Steam Pump Company, by Samuel Harrison and J. W. Sims; Monarch Valve Manufacturing Company, by W. D. Hosley; Lead Lined Iron Pipe Company, by Thomas E. Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould; H. Mueller Manufacturing Company, by A. C. Pilcher and G. A. Caldwell; National Meter Company, by C. H. Baldwin and J. G. Lufkin; Neptune Meter Company, by C. A. Vaughan, F. A. Smith, and H. H. Kinsey; Norwood Engineering Company, by H. W. Hosford and W. G. Ryan; Pitometer Company, by E. M. Blake; Pittsburg Meter Company, by T. C. Clifford and V. E. Arnold; Platt Iron Works Company, by T. H. Hayes; Rensselaer Manufacturing Company, by Fred S. Bates and C. L. Brown; Ross Valve Manufacturing Company, by William Ross; A. P. Smith Manufacturing Company, by F. N. Whitcomb and Anthony P. Smith; Thomson Meter Company, by E. M. Shedd, S. D. Higley, and W. S. Cetti; Union Meter Company, by L. P. Anderson, F. E. Hall, and C. F. Merrill; United Lead Company, by Frederick H. Craig; United States Cast Iron Pipe & Foundry Company, by Thomas H. McGechin and F. W. Nevins; Water Works Equipment Company, by W. H. Van Winkle and W. H. Van Winkle, Jr.; R. D. Wood & Co., by Charles R. Wood and Walter Wood.— 53.

Guests.

J. F. Beladeau, H. H. Hawkesworth, Pittsfield, Mass.; F. P. Martin, L. F. Ivers, West Springfield, Mass.; A. A. Adams, F. W. Dickinson, Edwin G. Rude, F. A. Holden, J. J. Fitzgerald, Mr. and Mrs. E. S. Green, Charles Davis, J. K. Barker, Mrs. H. P. Small, H. C. Emerson, George F. Merrill, H. T. Murphy, M. L. Miller, and E. T. Kavanaugh, Springfield, Mass.; L. B. Cummings, F. S. Dewey, Jr., and Chas. N. Oakes, Westfield, Mass.; W. A. Brown, Greenfield, Mass.; Mrs. Willard Kent, Narragansett Pier, R. I.; Mrs. Irving S. Wood, Providence, R. I.; P. J. Lucey, F. J. Millane, A. F. Sickman, Robert E. Newcomb, Patrick Gear, James F. Cleary, Miss Alice S. Corner, and Miss K. G. Sullivan, Mrs. E. A. Ellsworth, Holyoke, Mass.; Mrs. H. O. Smith, Leicester,

Mass.; T. A. Collins, Lawrence, Mass.; Mrs. D. H. Gilderson, Haverhill, Mass.; Mrs. Wm. H. Thomas, Hingham, Mass.; Mrs. D. N. Tower, Cohasset, Mass.; Mrs. L. M. Bancroft, Reading, Mass.; Mrs. W. H. Vaughn, Wellesley, Mass.; Mrs. George A. King, Miss King, Taunton, Mass.; Mrs. Murray Forbes, Greensburg, Pa.; Mr. H. P. Keegan, Cleveland, Ohio; Mr. R. Winthrop Pratt, Columbus, Ohio; Roscius C. Newell, Three Rivers, Mass.; James G. Hill, Lowell, Mass.; F. N. Carpenter, Northfield, Vt.; Bertram Brewer, Waltham, Mass.; F. S. Robinson, Waterford, N. Y.; George R. Taylor, Scranton, Pa.; W. H. Jackson, Providence, R. I.; Mrs. John Mayo, Bridgewater, Mass.; H. R. Cooper, Thompsonville, Conn.; Mrs. F. H. Luce, George C. Dickel, Woodhaven, N. Y.; C. A. Goodhue, Thompsonville, Conn.; A. E. Blackmer, Plymouth, Mass.; Joseph M. Brown, East Orange, N. J.; Mrs. W. H. Van Winkle, Thaddeus Newman, G. E. Sly, Frank C. Wright, A. E. Kornfeld, New York City; W. W. Bryan, Paterson, N. J.; Mrs. Ena B. Small, Portland, Me.; Mrs. Edward L. Peene, Yonkers, N. Y.; H. B. Morton, Bristol, Conn.; Edwin Leavitt, Somerville, Mass.; Mrs. E. M. Shedd, West Somerville, Mass.; John J. Barry, Chicopee, Mass.; Mrs. Frank L. Fuller, Harry S. Brown, F. C. Putney, P. H. Gallaher, J. R. Fletcher, T. P. Taylor, E. A. Stevens, Mrs. H. H. Kinsey, Miss Joan M. Ham. — 81.

[Names counted twice — 7.]

The convention was called to order at 12 M., on Wednesday, September 11, in the convention room at the Cooley Hotel, with President John C. Whitney in the chair.

PRESIDENT WHITNEY. I have to announce the opening of the Twenty-Sixth Annual Convention of the New England Water Works Association. We meet this year in a city which has faced and is facing difficult municipal problems in a broad-minded, businesslike way, and I take great pleasure in introducing the Hon. William E. Sanderson, Mayor of the city of Springfield.

MAYOR SANDERSON. *Mr. President, Ladies, and Members of the New England Water Works Association:* It is not my purpose to occupy your time to any extent with remarks of mine, knowing full well that you are here to consider problems which apply to your particular line of business. It is very true that Springfield is confronting problems of great magnitude, and particularly in your line lies one of them. The details of that problem will be presented to you very ably by the engineers of our Water Department.

I cannot help but appreciate — and the people appreciate — these gatherings, where there is an exchange of ideas on the problems confronted in the different localities from which you have the honor to come. It is the exchanging of those ideas which

makes it possible for us to attain the highest degree of efficiency and perfection in these problems which affect the people of our respective communities.

Gentlemen, it affords me great pleasure, on behalf of the city of Springfield, to extend to each and every one of you a most cordial greeting and hearty welcome. We trust that your stay in our city may be most pleasant and profitable to you, and that you may carry away with you pleasant memories of the city of Springfield.

Gentlemen, I thank you.

President Whitney. The Secretary has some applications for membership which have been passed upon by the Executive Committee, and which he will read. Mr. Secretary, will you read the applications that you have?

Secretary Kent. I have applications for membership from: Henry B. Lake, chemical engineer, Canadian Pacific Railway, Winnipeg, Manitoba; Edward Sutherland Stokes, medical officer and biologist to Metropolitan Board of Water Supply and Sewerage, Sydney, N. S. W., Australia; Arthur C. King, assistant engineer, Increased Water Supply, Springfield, Mass.; Cassius E. Gillette, recently chief engineer, Bureau of Filtration, Philadelphia, Pa.; William McCarthy, superintendent, Bluefield Water Works and Improvement Company, Bluefield, W. Va.; Harrie L. Davenport, water commissioner, South Framingham, Mass.; Carroll F. Story, assistant engineer, Springfield Water Department, Ludlow, Mass.; Henry Richards, trustee, Gardiner Water District, Gardiner, Me.; Frank L. Clapp, superintendent of Water Works, Stoughton, Mass.; and for Associate Membership, from United Lead Company, New York, N. Y.

These applications are all properly endorsed, and have been recommended by your Executive Committee.

President Whitney. You have heard the applications. What is your pleasure?

Mr. L. M. Bancroft. Mr. President, I move that the Secretary be authorized to cast one ballot for the election of the applicants named.

Motion seconded and carried. The Secretary thereupon cast a ballot, and the President declared the applicants duly elected.

Mr. R. J. Thomas. Mr. President, I move that the thanks of the Association be extended to his Honor the Mayor for meeting with us to-day.

Motion seconded and carried.

Meeting adjourned.

Afternoon Session, Wednesday, September 11, 1907.

President John C. Whitney in the chair.

President Whitney. The Secretary has some applications for membership which he will read.

Secretary Kent. We have applications from: J. H. Child, superintendent of water works, Wallingford, Conn.; Arthur B. Farnham, city engineer, Pittsfield, Mass.; H. O. Lacount, engineer and assistant secretary, Inspection Department, Associated Factory Mutual Insurance Companies, Boston, Mass.; R. R. Newman, civil engineer with William Wheeler, Boston, Mass.; W. G. Dryden, superintendent, Montreal Water and Power Company, Montreal, Canada; William H. Sutherland, assistant engineer, Montreal Water and Power Company, Montreal, Canada; Lawrence C. Brink, New Paltz, New York; P. F. Carmody, water commissioner, Holyoke, Mass.; and for Associate Membership, Monarch Valve and Manufacturing Company, Springfield, Mass.

These are all properly endorsed and recommended by your Executive Committee.

President Whitney. You have heard the list of applications. What action will you take?

Mr. Collins. Mr. President, I move that the Secretary cast one ballot and that they be declared elected.

Motion seconded and carried. The Secretary then cast a ballot, and the President declared the applicants elected.

Mr. Charles W. Sherman. Mr. President, the constitution requires that at some time during the convention a nominating committee be elected or appointed, to name officers for the ensuing year. In accordance with the usual custom, I offer a motion that the President appoint a nominating committee of five.

President Whitney. You have heard Mr. Sherman's motion. Is it seconded?

Motion seconded.

PRESIDENT WHITNEY. It is moved and seconded that the President be authorized to appoint a committee of five to bring in a list of officers for the ensuing year. All those in favor say Aye.

VOICES. Aye.

PRESIDENT WHITNEY. Contrary minded, No. It is a vote.

Mr. Elbert E. Lochridge, chief engineer, Springfield Water Works, then presented a description of the Springfield Water Works, illustrated by stereopticon. The paper was discussed by Messrs. Allen Hazen, Robert Spurr Weston, Murray Forbes, C. F. Story, M. F. Collins, R. J. Thomas, Wm. F. Codd, George A. Johnson, and L. P. Kinnicutt.

Meeting adjourned.

EVENING SESSION, WEDNESDAY, SEPTEMBER 11, 1907.

Mr. Allen Hazen gave a talk on his recent visit to Australia, illustrated with lantern slides of water works and other views of interest.

The next paper was "Description of Plant at Peabody, Mass., involving Construction of Tunnel, New Reservoir, New Pumping Station, and High Duty Worthington Pump," by F. A. Barbour, C. E., Boston, Mass.

Adjourned.

MORNING SESSION, THURSDAY, SEPTEMBER 12, 1907.

President Whitney in the chair, at the opening; later, Vice-President George A. King.

This session was devoted to the general subject of damages resulting from diversion of water. Mr. Charles T. Main, of Boston, read a paper entitled "Computation of the Value of Water Power, and the Damages caused by the Diversion of Water used for Power." Mr. Richard A. Hale, of Lawrence, Mass., followed with a paper on the subject of "Water Rights." A paper entitled "Damages Caused by the Diversion of Water Power," by Mr. Clemens Herschel, of New York, was presented by title, in the absence of the writer.

The discussion was taken up on these three papers jointly, and the following gentlemen took part: Messrs. H. K. Barrows, Leonard Metcalf, W. C. Hawley, Kenneth Allen, Charles T. Main,

George A. King, Richard A. Hale, Charles W. Sherman, J. H. Cook, E. L. Grimes, E. H. Foster, and A. A. Reimer. Mr. E. H. Foster offered the following motion:

"That a committee be appointed by the chair to approach the National Cotton Manufacturers' Association and invite them to appoint a committee, these committees to act as a joint committee to draw up a set of rules to govern the estimation of damage to water privileges by diversion."

Seconded.

Mr. Charles W. Sherman offered the following as a substitute motion:

"That a committee of five be appointed by the President to collect data relating to awards that have been made for damages resulting from the diversion of water; also to consider the practicability of joint action with the National Cotton Manufacturers' Association, or other organizations of mill owners, leading to the formulation of standard rules and methods of computing or assessing damages for the diversion of water."

The substitute motion was accepted by Mr. Foster, and, a vote being taken, it was adopted. (The President subsequently appointed as members of this committee, Messrs. Charles T. Main, Leonard Metcalf, R. A. Hale, Charles E. Chandler, and William Wheeler.)

The Chairman made the following announcement:

The South Norwalk, Conn., sand filters are being constructed for the purification of the public water supply. These filters present some novel features, and should be of considerable interest to members of this Association. The South Norwalk Water Commissioners would be glad to have as many members of the Association as possible visit their plant on Saturday next, and will furnish transportation by automobiles from the South Norwalk station to the filters, a distance of about nine miles, and provide a lunch. If any members of the Association desire to accept this invitation please give their names to the Secretary or Mr. H. W. Clark.

Adjourned.

Afternoon Session, Thursday, September 12.

President Whitney presided.

Mr. Bertram Brewer, city engineer of Waltham, Mass., read a paper on "The Waltham Reinforced Concrete Reservoir," illustrated by stereopticon. The paper was discussed by Messrs. T. H. McKenzie, Leonard Metcalf, H. K. Barrows, Kenneth Allen, Dabney H. Maury, W. C. Hawley, Allen Hazen, Walter H. Richards, A. A. Reimer, A. Prescott Folwell, Frank L. Fuller, and Mr. Brewer.

Mr. William R. Conard then read a paper entitled, "Cast-Iron Pipe Specifications." It was discussed by Messrs. T. H. McKenzie, W. H. Richards, Walter Wood, A. A. Reimer, Frank L. Fuller, and the author.

Adjourned.

Evening Session, Thursday, September 12.

Mr. Hiram A. Miller gave an illustrated talk on "The Charles River Basin."

The Secretary read applications for membership from the following persons:

J. D. Walker, Belfast, Me..; John J. Kirkpatrick, superintendent, Holyoke Water Works, Holyoke, Mass.; Frank J. Gifford, general foreman, Fall River Water Works, Fall River, Mass.; Chester R. McFarland, superintendent of Water Works, Tampa, Fla.,

all of which had been approved by the Executive Committee.

On motion, the Secretary was authorized to cast the favorable vote of the Association for the applicants, which he did, and they were declared elected.

The President announced his appointments to the committees previously authorized as follows:

Nominating Committee. — Dexter Brackett, Alfred D. Flinn, Robert C. P. Coggshall, Edwin C. Brooks, Frederick W. Gow.

Committee on Water Damages. — Charles T. Main, Leonard Metcalf, R. A. Hale, Charles E. Chandler, and William Wheeler.

President Whitney. The Association received an invitation from the Water Commission of South Norwalk to visit their filter plant on Saturday of this week. The invitation was received through Mr. H. W. Clark, but so few members have evinced a

disposition to make the excursion that it will have to be abandoned. Now, in reference to the excursion to-morrow, special trolley cars will leave the front of this hotel at nine o'clock sharp. That means the cars will leave at that time. Members must be on the sidewalk at least five minutes previous to that time.

Mr. E. M. Blake described briefly a new pitometer recording outfit for use in determining the slip of pumps.

Convention adjourned.

Friday, September 13, 1907.

In the forenoon the Association was taken by special electric cars to the works of the Chapman Valve Manufacturing Company, at Indian Orchard, and was entertained by that company. The manufacturing plant was of much interest, and so also was the excellent luncheon that followed. A vote of thanks to the Chapman Valve Manufacturing Company was proposed by Mr. R. J. Thomas, and was carried unanimously.

In the afternoon many of the members visited the Ludlow filters of the Springfield Water Works and others took advantage of the opportunity to visit the Springfield armory.

Report of Committee on Exhibits.

Mr. J. C. Whitney, President,

New England Water Works Association:

Dear Sir, — I hereby submit report of Committee on Exhibits at annual meeting held at Springfield, Mass., September 11–13.

The exhibitors were as follows:

National Meter Company	Meters.
Neptune Meter Company	Meters.
Pittsburg Meter Company	Meters.
A. P. Smith Manufacturing Company,	Photographs and samples of work.
Hersey Manufacturing Company . . .	Meters.
Thomson Meter Company	Meters.
International Steam Pump Company,	Worthington Meters.
Ross Valve Manufacturing Company .	Hydraulic blowing engine and pressure regulating devices.
The Fairbanks Company	Valves and hydrants.
Hays Manufacturing Company . . .	Shut-offs, lead connections and patent lead-pipe joints.

H. Mueller Manufacturing Company .	Shut-offs, tapping machine, and general water-works tools.
Monarch Valve Manufacturing Company,	Valves.
United Lead Company	Lead wool.
Union Water Meter Company	Meters and pressure regulators.
Hart Packing Company	Fibrous packing, steam and water.
Anderson Coupling Company	Patent lead pipe joints.
Lead Lined Iron Pipe Company . . .	Lead and tin-lined pipe and fittings.
The Pitometer Company	Pitometer.
Water Works Equipment Company .	Photos of tapping machines.
Central Foundry Company	Cast-iron pipe.
Fire and Water Publishing Company.	

Twenty-one associate members availed themselves of the opportunities offered to exhibit.

Space occupied by exhibits, 400 square feet.

Respectfully submitted,

EDWARD F. HUGHES, *Committee.*

EXECUTIVE COMMITTEE.

WEDNESDAY, June 26, 1907, 11.30 A.M.

Meeting of the Executive Committee of the New England Water Works Association, on steamer *Cape Ann, en route*, Boston to Gloucester.

Present: President Whitney, and members, Charles W. Sherman, D. N. Tower, Robert J. Thomas, L. M. Bancroft, George W. Batchelder, George A. King, and Willard Kent.

The following applications were received and recommended for active membership, viz.:

Henry B. Lake, Edmund Sutherland Stokes, Arthur C. King, Cassius E. Gillette, William McCarthy, Harrie L. Davenport, Carroll F. Story, Henry Richards, Frank L. Clapp.

Voted: That the next annual convention of this Association be held at Springfield, Mass., and that the Secretary be a committee to make the necessary arrangements therefor.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

BOSTON, MASS.,
August 20, 1907.

Meeting of the Executive Committee of the New England Water Works Association at Tremont Temple, pursuant to call issued by the Secretary at the request of the President.

Present: President John C. Whitney, and members, Charles W. Sherman, George A. King, A. E. Martin, Lewis M. Bancroft, Robert J. Thomas, and Willard Kent.

The President appointed Mr. Edward F. Hughes of the Chapman Valve Manufacturing Company, 94 Pearl Street, Boston, Mass., a committee in charge of exhibits of Associates for the September convention of 1907.

A communication from the Chapman Valve Manufacturing Company, inviting the Association to inspect their works and

partake of lunch was received and accepted for Friday, September 13.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

SPRINGFIELD, MASS.,
Wednesday, September 11, 1907.

A meeting of the Executive Committee of the New England Water Works Association was held at the Cooley Hotel at 2.30 P.M.

Present: President John C. Whitney, and members, George A. King, A. E. Martin, D. N. Tower, George W. Batchelder, Lewis M. Bancroft, Charles W. Sherman, Robert J. Thomas, and Willard Kent.

The following applications were received and recommended for membership:

J. H. Child, superintendent, Wallingford, Conn.; Arthur B. Farnham, city engineer, Pittsfield, Mass.; H. O. Lacount, engineer and assistant secretary, Inspection Department, Associated Factory Mutual Fire Insurance Companies, Boston, Mass.; R. R. Newman, civil engineer with William Wheeler, Boston, Mass.; John J. Kirkpatrick, superintendent, Holyoke Water Department, Holyoke, Mass.; W. G. Dryden, superintendent, Montreal Water and Power Company, Montreal, Canada; Wm. H. Sutherland, assistant engineer, Montreal Water and Power Company, Montreal, Canada; Lawrence C. Brink, New Paltz, N. Y.; Monarch Valve and Manufacturing Company, Valve Manufacturers, Springfield, Mass.; United Lead Company, Manufacturers, Lead Wool, New York City; Frank J. Gifford, general foreman, Fall River, Mass.; P. J. Carmody, water commissioner, Holyoke, Mass.; J. D. Walker, Belfast, Me.; Chester R. McFarland, superintendent, Water Works, Tampa, Fla.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

OBITUARY.

Louis P. Collins, ex-mayor of Lawrence, Mass., died at his home in Manchester, N. H., on October 1, 1907, after a lingering illness. He had removed there from Lawrence three years ago. He was treasurer and manager of the Derryfield Lumber Company.

He was born in Sheffield, Ontario, in 1851. He located in Lawrence when a boy, going to work in a sash and blind shop. He gradually advanced until he became treasurer and manager of the Briggs & Allen Company, of that city.

In 1888 he entered politics, and was that year chosen a member of the Lawrence city council. The following year he was elected alderman, and in 1890 was elected mayor.

He joined the New England Water Works Association on December 12, 1894.

BOOK REVIEWS.

Clean Water and How to Get It. By Allen Hazen. New York: John Wiley & Sons. 1907. $5\frac{1}{2}$ x 8 inches. vi + 178 pp. With 14 half-tone plates. Price, $1.50.

Mr. Hazen says in his preface, " Its object is to help beginners to understand something of first principles. Members of water boards and water works superintendents have largely passed this stage, and it is therefore not for them."

While this may have been the author's idea in preparing the book, and while most water-works engineers, superintendents, and experienced members of water boards have, no doubt, more or less clear ideas on most of the subjects referred to, very few of them, it is safe to say, have so complete information upon these subjects that they will not learn much that will prove valuable, as well as interesting, from this little book.

The titles of the chapters are: Impounding Reservoir Supplies; Water Supplies from Small Lakes; Supplies from the Great Lakes; Water Supplies from Rivers; Ground Water Supplies; On the Action of Water on Iron Pipes and the Effect thereof on the Quality of the Water; Development of Water Purification in America; On the Nature of the Methods of Purifying Water; On the Application of the Methods of Water Purification, arranged according to the Matters to be removed by the Treatment; Storage of Filtered Water; On the Required Sizes of Filters and Other Parts of Water Works; As to the Pressure under which Water is to be delivered; On the Use and Measurement of Water; Some Financial Aspects; The Laying Out and Construction of Works; On the Financial Management of Publicly Owned Water Works.

To one who knows of Mr. Hazen's broad experience in these lines and the clearness with which he writes, it is hardly necessary to say more; to others, no better advice can be given than to get the book and see for themselves.

Ice Formation, with Special Reference to Anchor Ice and Frazil. By Howard T. Barnes, Associate Professor of Physics, McGill University. New York: John Wiley & Sons. 1906. 6 x 9 inches. 257 pp., 40 figs. $3.00.

This book should prove very valuable to those who have to do with the operation of water-works intakes or water-power plants in the northern part of the country, where stoppages from ice are not infrequent, or are avoided only by great care and constant vigilance while the temperature remains below the freezing point.

The St. Lawrence River at Montreal has perhaps given more trouble in this way than any other stream, not only on account of the considerable use for

power, but also because the obstruction caused by ice in the river at the foot of the Lachine Rapids has caused many destructive floods in Montreal. This has caused the problem to be studied there with particular thoroughness, and Professor Barnes has utilized the results of the studies in this book.

Considerable space is devoted to the physical laws relating to the transmission of heat and the formation of ice; to temperature measurements, and to the theories accounting for frazil and anchor ice; and, finally, there is a chapter on methods of overcoming the ice problem in engineering work. To the engineer, this chapter is the most important, and it is to be regretted that it constitutes but 23 pages, or less than 10 per cent. of the book.

THE ANALYSIS AND SOFTENING OF BOILER FEED WATER. By Edmund Wehrenfennig and Fritz Wehrenfennig (Austria). Translated by D. W. Patterson. New York: John Wiley & Sons. 1906. 6 x 9 inches. xiv + 290 pp., 171 figs. $4.00.

This book deals with a problem with which New England water users, fortunately, have little to do, since the waters of this section are generally soft. In the greater part of the country, however, the natural waters, whether derived from streams, lakes, or underground sources, are hard, and their use in steam boilers results in the formation of much scale, except where great precautions are taken. With some waters the use of a suitable boiler compound and a comparatively frequent washing out of the boiler serve to prevent the formation of scale; others, however, can only be rendered fit for boiler use by a chemical softening process.

In this country water softening has been most frequently resorted to by the railroads and by industrial corporations requiring softer water for boiler feeding than could be obtained except by treatment; but there are a few municipal water supplies which are softened, and it is probably safe to predict that a much larger number of public water supplies will be softened in the future.

The present book treats the problem of water softening from both a chemical and an operating point of view. It is prepared with especial reference to railroad water supplies, but the principles are, of course, equally applicable to other water supplies. It naturally contains no reference to American experience in this work, but the explanation of principles and methods seems very complete. The chapters on "Determination of the Amounts of Reagents" and "Testing the Softening" should prove especially valuable to any one having to do with a water-softening plant.

ELEMENTS OF SANITARY ENGINEERING. By Mansfield Merriman. Third edition. New York: John Wiley & Sons. 1906. 6 x 9 inches. 252 pp., 46 figs. $2.00.

The author says in his preface: "While this volume is primarily intended for the use of students in engineering colleges, its plan and arrangement are

materially different from those of other text-books on water supply and sewerage. The effort has been made to present the subject clearly and concisely in. the smallest possible space, giving greater prominence to fundamental principles than to details of construction and operation. It is also hoped that the book may prove useful to municipal officers who have supervision of sanitary works as well as to the public in general, for it presents the guiding principles which should be observed in order to secure a pure water supply or an efficient system of sewerage."

The book is mainly descriptive. It is in no sense a text-book on the design of sanitary works of any kind. The titles of the chapters give a general idea of the subjects treated. They are: Sanitary Science; Water and Its Purification; Water Supply Systems; Sewerage Systems; Disposal of Sewage; Refuse and Garbage; Appendix.

This work should be an excellent text-book for imparting to students a general view of the whole field of sanitary engineering, and any person desiring a broad view of the general subject should find it very interesting and not difficult reading.

The Venturi Meter and the First Twenty Years of Its Existence. By Clemens Herschel. Pamphlet. 6 x 9 inches. 48 pp. Published by Builders Iron Foundry, Providence, R. I.

While in a sense a trade publication, this little paper is so interesting as an historical review of the invention of this important hydraulic instrument, of its registers, and of the uses to which it has been put, that it well deserves mention in this place.

The Disinfection of Sewage Effluents for the Protection of Public Water Supplies. By Karl F. Kellerman, R. Winthrop Pratt, and A. Elliott Kimberley. United States Department of Agriculture, Bureau of Plant Industry. Bulletin No. 115. Washington: Government Printing Office. 1907. Pamphlet. 6 x 9 inches. 47 pp.

A report of many tests of disinfection of sewage, at several places in Ohio, by the use of calcium hypochlorite, copper sulphate, and chlorin.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XXI. December, 1907. No. 4.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

THE WALTHAM RESERVOIR.

BY BERTRAM BREWER, CITY ENGINEER, WALTHAM, MASS.

[*Read September 12, 1907.*]

The Waltham reservoir is the fourth large reinforced concrete or mortar standpipe to be built in this country. It is the largest of the four.

The first structure of this character was built at Fort Revere, Hull, Mass., in 1902, of 1: 2: 4 concrete. The internal dimensions are 50 feet high by 20 feet in diameter, with a capacity of 118 000 gallons. This was a remarkable job, and very successful. It was constructed with very thin walls, only 6¼ inches at the base and 3½ inches at the top. It has been fully described in the JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, March, 1905.

About this time, or shortly after, in 1903, a reinforced standpipe of 1: 3 mortar was constructed in Milford, Ohio. This was 81 feet high by 14 feet in diameter, with walls 9 inches thick at the base and 5 inches at the top.

In 1905 the Aberthaw Construction Company constructed for the town of Attleboro, Mass., a large reinforced concrete standpipe 100 feet high and 50 feet in diameter. This was built of 1: 2 : 4 concrete with walls 18 inches thick at the bottom and battered to 8 inches at the top, and holds 1 500 000 gallons.

The Waltham reservoir was built in 1906 of 1: 2 : 4 concrete and is 35 feet high and 100 feet in diameter. The walls of this reservoir are 18 inches thick at the base, battered to 12 inches at the top. It holds over 2 000 000 gallons.

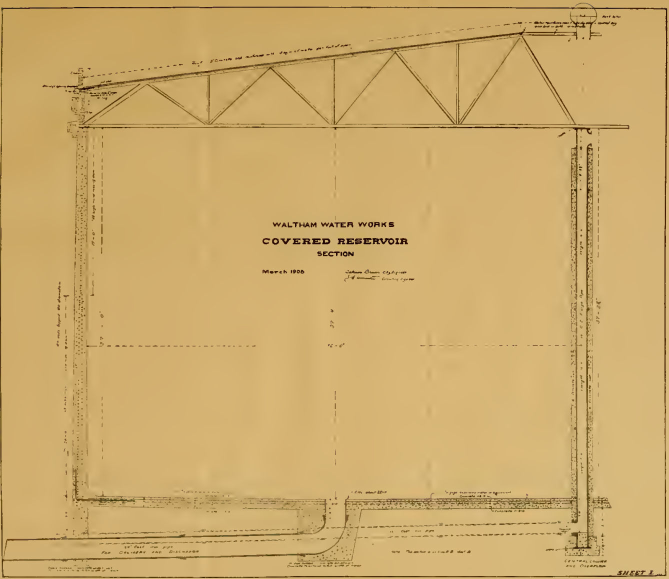
One writer, in a printed statement, described the concrete reservoir, built for the water department of the city of Waltham in the summer of 1906, as "a wonderful example of reinforced concrete construction." I may truly say, however, that this type of structure was only decided upon after careful preparation, covering a long period of time. This preparation included numerous laboratory tests, correspondence and consultation with several engineers, and several trips to Attleboro, including a big inroad upon the good nature of Mr. Snell.

The city government was reminded that the general public would not understand the details or difficulties involved in such a novel construction as that we proposed to undertake, and that it would be very easy for some misinformed or irresponsible person to infuse the public mind with the idea that the structure was unexpectedly leaky and dangerous, even though those in charge might know that such was not the case. Attention was also called to the fact that, as in previous structures of this character, the materials and the methods employed were such that it might require considerable time in which to stop up such seepage as in our best judgment could not be allowed to remain, and might preclude the possibility of absolutely watertight work.

Nevertheless, as we showed a saving of $2 300 over a steel structure of similar size, with no maintenance cost for the concrete, and were able to give good reasons for our faith in our plans and specifications, we were told to go ahead and were supplied with suitable funds.

Invitations were sent out March 13, 1906, and bids were opened March 22. On April 4, after extended negotiations, a contract was made with Simpson Bros. Corporation, of Boston, the lowest of four bidders, for the construction of the reservoir, for the sum of $25 786. Work was begun during the week beginning April 9, and the reservoir was ready to fill on August 28.

The bottom of the reservoir rests mostly on ledge and is 12 inches thick except under the wall where it is not less than 3 feet 6 inches deep. It is reinforced with a layer of expanded metal near the surface to prevent shrinkage cracks. The floor is troweled to a granolithic finish. Bent rods were placed in this base spaced every 12 inches. They extend 6 feet into the base of the reservoir



Note that there are three rows of reinforcing rods in the lower 20 feet of the wall, instead of two rows as shown; and two rows in the upper 17 feet, instead of one row as shown.

and 3 feet up into the wall. Enough steel reinforcement was used in the walls to keep the tensile stress within a 12 000 pound limit. The rods were arranged in three rows up to 20 feet and then in two rows in the next 17 feet. The roof consists of a reinforced concrete slab 3 inches thick, supported by steel trusses radiating from a central, concrete covered, pipe column, which serves also as an overflow. These trusses are 3 feet 8 inches high at the outside ends and an ornamental enclosure wall was built up around and above them, making the total height of the side walls 43 feet. Except in the foundations and lower 6 inches of the floor, which were composed of a 1: 3: 6 mixture, the concrete was proportioned at the rate of 90 pounds cement to 2 cubic feet sand and 4 cubic feet stone and 5 pounds hydrated lime. (See Plate I.)

The walls were reinforced with $1\frac{1}{8}$-inch round rods specified to fulfill the American Steel Manufacturers' standard specifications for railway bridge steel. The jointing of the rods was made, in every case, by a lap of 40 diameters. They were rolled on the ground to the required radius and occasionally tied at the ends. The cement was required to conform to the standards for Portland cement adopted by the American Society for Testing Materials. Most of the stone and all of the sand was screened from a gravel bank on city land not far from the site.

As most builders have found to their sorrow, there are certain inherent difficulties in manufacturing concrete which usually render it permeable to water. It was, therefore with great study and care in this particular that the specifications for this reservoir were prepared. Previous experience in the erection of the three concrete standpipes already mentioned, Milford, Fort Revere, and Attleboro, was carefully investigated. In this climate, it is perhaps not so much a question how to stop all percolation as it is to reduce it to so small a quantity as to avoid injury from frost. The peculiar, if not unusual, precautions taken to make this building a success may be grouped under the following heads:

First. The character of the sand and gravel which entered into the aggregate.

Second. Some waterproofing material or compound to be added.

Third. The method of placing steel and holding it in place.

Fourth. Forms.

Fifth. Making the joints and caring for the concrete as it set.

Sixth. Interior finish of walls.

Permeability tests were made with blocks of uniform section prepared from the materials to be used in the aggregate in different proportions in order to ascertain the most impermeable mixture. We determined to use gravel and sand from a bank on water works land not far from the site, the stones to be not over 1½ inches in diameter. Specimens were prepared with gravel from the aforesaid bank, mixed in the proportion of 1: 2: 4 with the ordinary bank sand and also with ⅔ bank sand and ⅓ fine sand. We concluded, after examining the various waterproofing materials on the market, to try two,— Medusa compound, manufactured by the Sandusky Portland Cement Company, and hydrated lime. Specimens having an admixture of 2, 4, 5, 7, and 9 per cent. of the weight of the cement were prepared and subjected to a pressure averaging about 70 pounds. We found that the use of a considerable proportion of fine sand was productive of good results, and that Medusa compound, when added to the extent of 4 per cent. of the weight of the cement, made a practically impermeable mixture. With the addition of hydrated lime to the extent of 5 per cent., the amount of water passing the concrete applied at 80 pounds pressure at the end of two months averaged 38 grams per minute in 2 specimens, and in a further test of 6 specimens where from 5 to 9 per cent. of the lime was added to the cement, the sand and stone being sifted in accordance with our specifications, 5 of the 6 specimens were absolutely impervious at 61 to 68 pounds pressure after standing for fourteen days.

Medusa compound is expensive. Its use to the extent of 4 per cent. in the body of the concrete would have added over $2 000 to the cost of the structure. Lime is comparatively cheap and effective, so we decided to depend upon those proportions of stone and sand which mechanical analyses of our materials showed to be the most dense, using hydrated lime in the concrete, to the extent of 5 per cent. of the weight of the cement, and lime and Medusa compound in the plaster and wash for the inside.

The specifications read as follows:

"All sand shall be clean, free from clay, loam, sticks, organic matter, or other impurities. In sand for concrete, not more than 5 per cent. residue shall be left on a No. 8 sieve, and the percentage passing a No. 50 sieve shall be so governed as to produce a concrete as watertight as possible in accordance with the instructions to be given by the engineer.*

"Sand used in plastering or grout must be of a fineness satisfactory to the engineer.

"Stone used in watertight work shall be of clean pebbles, screened from a gravel bank, and free from foreign matter. Clay or dirt adhering to the pebbles shall be washed from them before placing upon the mixing platform in hand-mixing or before placing in the mixer in machine-mixing. No stones in watertight work shall be more than 1½ inches in diameter and the stones shall be screened on a ¼-inch sieve in such a manner that by laboratory test not less than 15 per cent. nor more than 20 per cent. of materials shall pass a ¼-inch sieve.

"The sizes of the pebbles shall be so graded as to produce a concrete containing a minimum percentage of voids in accordance with the instructions given from time to time by the engineer. If the sizes of the pebbles as screened from the bank are not satisfactory to the engineer, it may be required that two sizes of stones shall be separately screened and measured.

"If preferred, broken stone, of hard and durable rock, of sizes satisfactory to the engineer, may be used for the foundations and that part of the reservoir above high water.

"In adding hydrated lime or other similar waterproofing ingredient or ingredients, the quantity prescribed shall be weighed or measured for each batch and shall be introduced into the mixer before adding any of the other materials and the mixer turned a sufficient number of times to form a milk of uniform color. If used in hand-mixed concrete it shall be well stirred into the water to be used in mixing the batch of concrete."

The steel supports for holding the rods were spaced 13.25 feet apart. They show very clearly in one of the cuts (Plate II, Fig. 2). The reinforcing rods, after being rolled very carefully to the required radius, were placed in the angles of these lattice-work supports. This method of supporting steel was worked out in detail by the contractor from suggestions made to him before the contract was signed, and proved entirely successful. With a lap of 40 diameters we secured, in each of the steel hoops, the ultimate strength of the steel at every point. The danger that some sections of the

* Fifteen per cent. was decided upon and used.

concrete might peel off at the outer line of steel rods was duly considered by us, and one of the precautions taken consisted in distributing the rods as much as possible through the section of concrete. In a structure of this character this possibility is a conclusive argument for the use of round rods.

Not only did we come to an early agreement with the contractor as to steel supports for the rods, but we made plans with him as to forms. These were erected in sections 3 feet high and about 5 feet long, 60 to the circle. Every outside form had a corresponding inside section which was tied to it with four ½-inch bolts extending through the wall. These bolts were in three parts; the middle, with the two heads into which it was screwed at either end, was permanently built into the wall, while the two outer parts were unscrewed from the outer ends of the heads upon removing the forms. The contractor built two complete sets of these forms, or enough for 6 feet of wall. The difference in lengths due to the batter of the outside of the wall was adjusted at the joints as the building progressed.

Rich concrete can be made waterproof much more readily by using well graded gravel. The rounded pebbles pack easily and readily produce a dense concrete. I believe that lime also is a valuable adjunct. The greatest care in selection of materials, however, cannot overcome the evils due to careless mixing or placing, and the bane of such extensive operations in watertight work still remains in the difficulties connected with making tight joints where new work joins the old. The following specification was devised to cover this point:

"Before laying concrete on rock surfaces the latter shall be swept clean of all *débris* and dirt and *wetted* when directed.

"Where one day's work joins another, or when new concrete or a plastic surface is added to old concrete which has begun to set, special precautions must be taken. The old surface shall be thoroughly cleaned of all dirt and scum or *laitance.* This *laitance* shall be entirely brushed out with steel brushes, or other implements satisfactory to the engineer, down to hard material. The old concrete when cleaned of all *débris* and dirt shall be carefully wet down and a thin layer of neat cement grout thoroughly brushed in and the new concrete added before the grout has time to set.

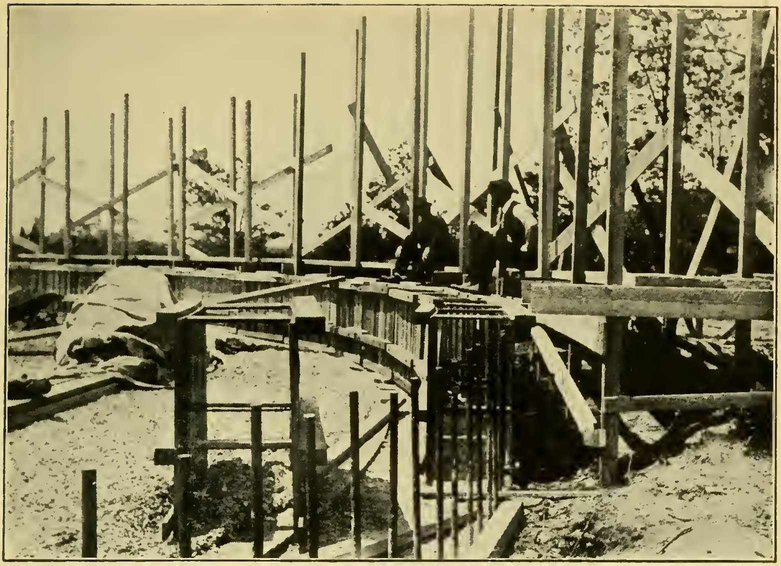


FIG. 1. REINFORCEMENT AND FORMS AT BASE OF WALL.

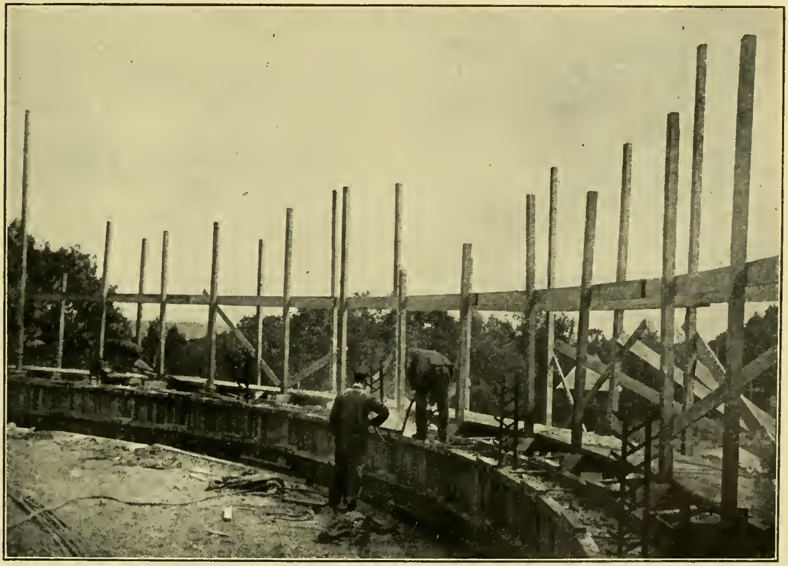


FIG. 2. LOWER PART OF WALL, WITH SUPPORTS FOR REINFORCEMENT RINGS.

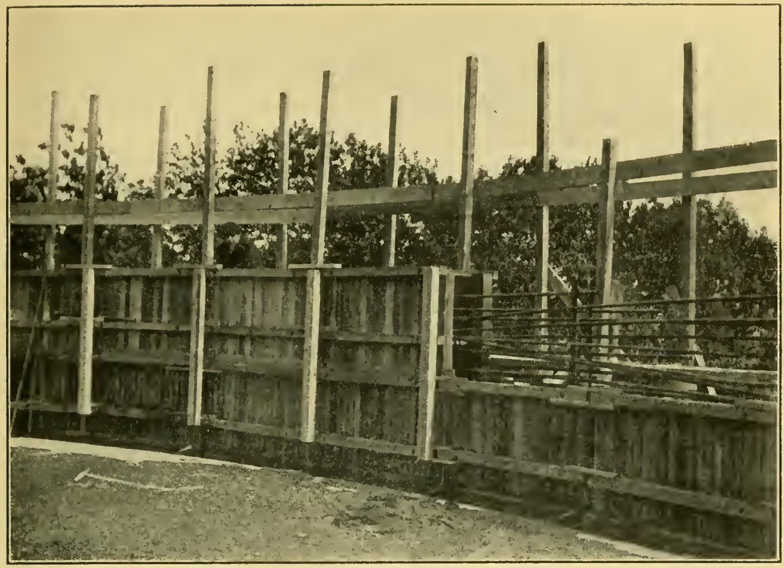


Fig. 1. Method of Supporting Wall Forms.

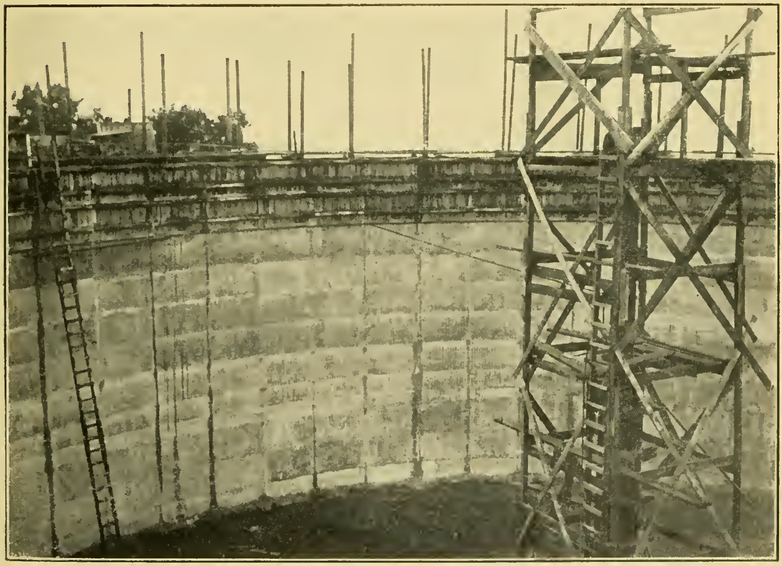


Fig. 2. Interior of Wall during Construction.

"As an additional precaution for securing a good bond, a groove at least 4 inches deep and 3 inches wide shall be constructed in the top of any portion of the wall allowed to stand and set."

New concrete was covered and wet down daily for a month, but, except for a small quantity of water in the bottom, no attempt was made to fill the reservoir until it was completed.

We determined, if possible, to get a waterproof concrete and in no wise to depend on the inside coating. That did not prevent, however, a thorough investigation of possible methods and the use of such as we thought best. The Hull and Attleboro standpipes were plastered, in the first case successfully and in the second case the Sylvester coating of soap and alum was finally resorted to, to make the structure satisfactorily tight. Our specification as to finish of floor and walls was as follows:

"A granolithic finish is to be troweled on to the surface of the floor by skilled mechanics at the time it is built. Said finish shall be carried up to the top of the curve at the junction of the floor and wall. Special care shall be taken to avoid any joints in the work.

"The contractor shall remove forms as soon as possible, and shall immediately treat the inside surface of the walls as follows: He shall remove all loose or unset material from the surface. He shall use special care at the joints and between layers of concrete, and, after cleaning them out and jointing with neat cement, the wall for a distance of 9 feet up from the top of the curve at the junction of the floor and wall shall be plastered by skilled mechanics with mortar mixed and placed as directed by the engineer. For the remainder of the wall, after cleaning and jointing as above specified, he shall apply two thin coatings of Portland cement grout and brush each in thoroughly, taking special pains at the joints."

For plastering, a mixture of 1 of cement to 3 of sand was used with the addition of hydrated lime to the extent of 10 per cent. and Medusa compound to the extent of 3 per cent. of the weight of the cement.

The brush coat consisted of a 3 to 2 mixture of cement and sand with 5 per cent. of the Medusa compound added.

The 24-inch inlet pipe, which, by the way, also serves as an outlet, is located half way between the wall and the central column. It is flush with the surface of the floor.

In a tank of this size we do not consider that there is any danger from ice. Ice forms in such fashion, little by little, that

the theoretical bursting pressure could not be applied at any one spot at any one time. The level of the water is constantly changing, and, in an underground supply like Waltham's, the water is comparatively warm in cold weather.

A candid statement of his mistakes by an intelligent man is often of more value than whole pages of description. I can truly say, however, after one year's use that there are very few mistakes to record; certainly, every structural difficulty was met as we expected.

There are two points which I desire to mention:

First, we allowed the contractor to use bolts with round shoulders to tie the forms together. After the wall was built and when unscrewing the outside sections to remove forms, the workmen, largely owing to their shape, occasionally jarred or moved and sometimes turned the permanent section, with the result that when the tank was filled, at many of these bolt holes there were noticeable damp spots. At the present writing these have practically silted up. We should have insisted on the square-headed bolts originally agreed upon.

Except in rainy weather, when it is not so important, we found that we could build 3 feet of wall in two and one-half days, and this should have been the limiting time. In one case, owing to delay in assembling a larger steam plant, the contractor allowed a section of old work to stand for five days in hot, dry weather before building on new wall, and that particular joint has shown the most seepage.

The body of the wall is not, and never has been, porous. The seepage, which has been very slight, and mostly such as the sun will dry up, has been confined to a very thin film at the joints, and to the bolt holes. Nothing has been done to the reservoir since it was first filled except that an uninspected third brush coat was applied at the joints by unskilled labor. Soon after the reservoir was put into use there was a considerable efflorescence, and a noticeable stalactite formation began to appear on the outer wall. I believe that the excess of free lime is certainly closing up the pores. The seepage has grown markedly less with use and no ill results followed the extreme cold of our last winter.

As already hinted, the problems connected with a large water-

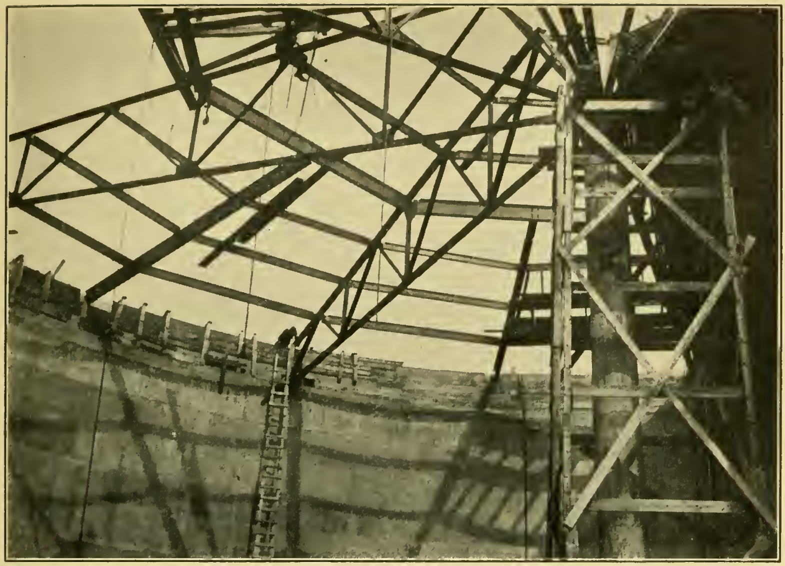


FIG. 1. PLACING ROOF TRUSSES.

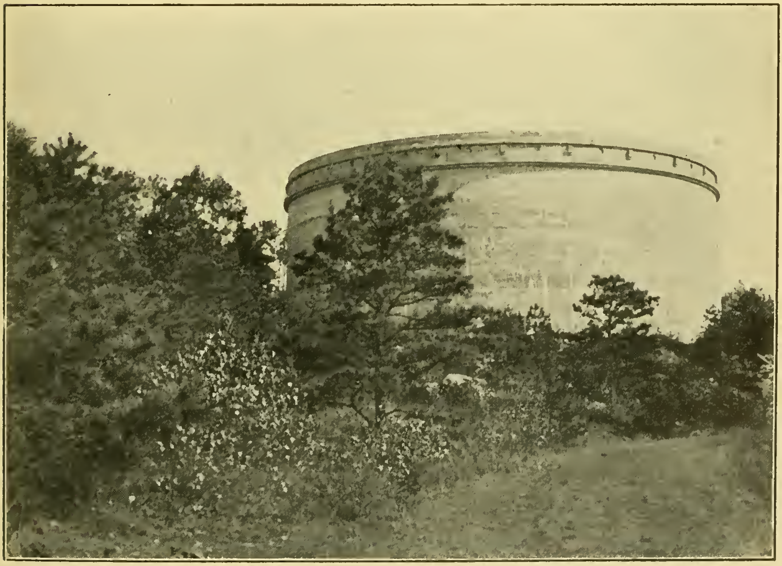


FIG. 2. VIEW OF COMPLETED RESERVOIR.

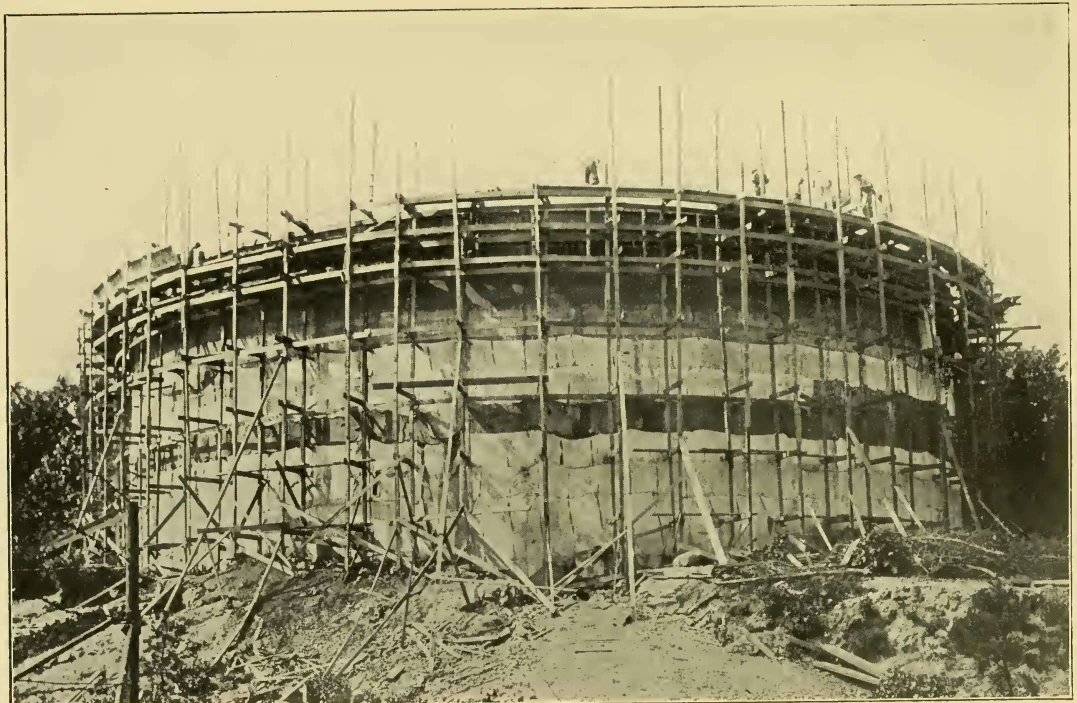


Fig. 1. General Appearance of Reservoir during Construction.

Fig. 2. Lime Formations on Surface.

proof concrete structure are very different from those incidental to the small tank. In the fall of 1906 I built a plain concrete tank in the ground, 50 feet from and below the river, with city labor, in which the concrete itself has been from the first absolutely watertight, and has shown no seepage whatever. This tank is 18 feet in diameter and about 18 feet deep, with 10-inch walls.

Two inspectors were employed at the reservoir while work was going on. One was stationed at the mixer and the other attended to the work on the wall. These men were not only interested and faithful but the principal inspector was especially skilled in concrete work. The inspection was of the best and is, I consider, an essential feature of our success.

The architectural features were carefully planned. We fixed upon good proportions to begin with and decided, after thorough investigation into a practical way to secure it without additional cost, upon battered walls. No difficulty was encountered in securing this important architectural effect, and, as a matter of fact, the amount of concrete, and therefore the cost, was considerably reduced thereby.

Mr. J. R. Worcester, the consulting engineer, who is a fellow-townsman, shared with me the responsibility for the design and specifications for this work.

DISCUSSION.

Mr. T. H. McKenzie.* May I inquire of Mr. Brewer whether the reservoir is built on earth or rock bottom?

Mr. Brewer. It was mostly ledge.

Mr. McKenzie. What was the thickness of the bottom?

Mr. Brewer. Twelve inches.

Mr. McKenzie. Can you give us any idea what was the cost per cubic yard of such a tank, including the bottom? That is, a sort of lump estimate of how much it cost per cubic yard, including everything, the forms and reinforcing.

Mr. Brewer. I should say from $20 to $25 per cubic yard, including the entire cost of the reservoir as completed. Of course I did not estimate it in that way. A remarkable thing in connec-

* Civil Engineer, Southington, Conn.

tion with that question was that the contract was let for within a few hundred dollars of my estimate.

Mr. McKenzie. Could you tell us what was your estimate?

Mr. Brewer. I stated the cost in my paper; it was $26 000.

Mr. McKenzie. Could you tell us the dimension?

Mr. Brewer. One hundred feet in diameter, 35 feet to high water, 43 feet over all.

Mr. Leonard Metcalf.* Do you remember, Mr. Brewer, what that amounted to per cubic yard in round numbers?

Mr. Brewer. I estimated the wall concrete, aside from the forms in steel, as about $8 for the work.

Mr. Metcalf. I mean including the steel; in other words, the total cost per cubic yard of the structure.

Mr. Brewer. Of course a very different unit price would apply to the bottom.

Mr. Metcalf. Yes; that should be separate, of course.

Mr. Brewer. The concrete in the bottom cost about $7.50 per cubic yard, while that in the walls and roof cost about $23.

Mr. Metcalf. Mr. President, I have been immensely interested in the discussion of this structure, which it seems to me is a very creditable one indeed, and I should like to ask Mr. Brewer about the method of preparing the joints before depositing the fresh layer of concrete on the old. He spoke, I believe, of removing the forms as soon as possible and putting on the plaster coating on the inside. Did he at that time have the surface of the concrete washed down and cleaned, or was that done after the new forms were erected, and just prior to applying the concrete? I ask that for the reason that inside of such narrow forms as these, and with the steel in place, I should think it would be pretty difficult to do that work after the forms were in place.

Mr. Brewer. The cleaning was always done before the new forms were erected. The wall, as soon as sufficiently set, was cleaned, thoroughly cleaned, with steel brushes. Then it was washed out very thoroughly with water from the hose, — we got it all as clean as we possibly could, — and then new forms were added. By the time the contractor was ready to fill the new forms, more or less dirt had collected from some cause or other.

* Consulting Engineer, Boston, Mass.

We were very careful to clean this out, give the old concrete another thorough washing, and make sure that it was all right before starting the new wall. Then, just before putting the new concrete on to the old, the grout was applied.

Mr. Metcalf. That was done with brooms, or something of that sort?

Mr. Brewer. Yes, sir.

Mr. Metcalf. Will you inform us what was the size of the largest slab used in the roof?

Mr. Brewer. It shows on the plan — about 12 feet. The roof was designed for a load of 90 pounds, 60 pounds dead and 30 pounds live load.

Mr. Metcalf. You used a thickness of 3 inches, figuring on a slab of 12 feet?

Mr. Brewer. Four inches in the center slab; 3 inches elsewhere.

Mr. H. K. Barrows.* May I inquire, has the tank been filled?

Mr. Brewer. It has; yes, sir. It has been in use now nearly a year.

Mr. Barrows. There is no settlement between the earth foundation and the ledge foundation, as far as you know?

Mr. Brewer. No, sir.

Mr. Wm. F. Codd.† I should like to inquire, in case the standpipe should leak steadily, whether the rods would be likely to rust and lose their strength.

Mr. Brewer. I don't think we would allow it to "leak steadily." We don't expect it to leak. It hasn't leaked this year, and after going through last winter I don't think it ever will. There are many things we might do to it if it did leak to such an extent as to cause any apprehension.

Mr. Kenneth Allen.‡ Mr. President, about two years ago I built a reinforced concrete coal pocket similar in some respects to this tank. It was 30 feet in diameter and 33 feet high inside, with a pyramidal top and conical bottom, supported on two annular cylinders, and the capacity was 400 tons. Of course it wasn't necessary to have it watertight.

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* Civil Engineer, Boston, Mass.
† Superintendent of Water Works, Nantucket, Mass.
‡ Division Engineer, Baltimore Sewerage Commission.

After placing the first set of rather long vertical reinforcing bars we had a very high wind without any apparent effect, but shortly after we discovered, by hammering, that three or four pilasters in which these were placed were not sound. Before completion the concrete in these was cut out and we found that the steel reinforcement had separated from the concrete. The material was in good condition and hadn't cracked, but if it had done so and if the structure had been designed to hold water, the result can be imagined. After noting the above defects greater precautions were taken to keep the bars from swaying, the pilasters were repaired, and the work finished without further trouble.

The proper securing of reinforcing rods from vibration is very important, especially in a tank of this kind, and I was interested in the very neat device used by the contractor for this purpose in Waltham.

Mr. Brewer. In answer to the question about the possibility of the steel rusting, in the photographs of another reservoir that I have shown I think that steel was exposed two or three months, if not longer, — may be four or five, — and when I saw it there was no sign of rust on it. It was wet, quite wet, at the time. I suppose there is a safeguard in the alkaline nature of the water that passes through concrete that prevents rusting. You will find the facts stated in the account of the Attleboro reservoir in the Journal.*

Mr. McKenzie. I think the most uncertain thing about reinforced concrete tanks is the matter of the life of the steel reinforcement. They will have to be used a sufficient length of time to determine the life of the steel rods. I had an experience in Meriden taking up a cement and sheet-iron pipe of the very best make. Our friend Mr. Bishop had charge of making and laying it. Nine years after they were laid we took them up and a large proportion of the sheet iron that was originally a quarter of an inch thick, or thicker, was entirely rusted out. The cement was from 2½ to 3 inches thick on the outside and from 1½ to 2 inches thick on the inside. Where the cement had adhered to the pipe it was perfectly bright, good, and strong, and where the cement had not adhered to the pipe there was simply a film of rust between

* September, 1906.

the two coatings of cement. Three fourths of the pipe was just a film of rust; practically no iron there at all. I don't know whether there would be the same result with a tank, whether the concrete would be sufficiently porous in a tank like the one that has just been described, so that the rods would corrode in any reasonable length of time. I don't believe any one can tell us what would be the life of the tank, on account of the porosity of the cement.

President Whitney. We should like to hear from Mr. Maury on the subject.

Mr. Dabney H. Maury.* Mr. President and gentlemen: I am afraid what little I may have to add to this discussion is not directly in the line of Mr. Brewer's very interesting paper for the reason that the reinforced concrete reservoir which I shall mention is not of exactly the same sort as Mr. Brewer's. His structure was built as a standpipe and depended upon the ultimate strength of the reinforcement to resist rupture. The structure I have in mind was built as a wall, with a gravity section. Yet it may be of interest here to say a little about it because it is remarkable for at least two things: In the first place, for its size, which was 300 feet inside diameter, 15 feet deep at the wall, and 25 feet deep at the center; and in the second place, for the conscientious care which was displayed by the contractor in the construction of a piece of work on which he was making no money.

A third feature which caused some comment was the small cost per million gallons of capacity of this reservoir. In addition to the reinforced concrete in wall and bottom, the work included 30 000 cubic yards of excavation and embankment; 100 feet or so of 24-inch pipe, with a number of gates and fittings of the same size laid in quite a deep trench; and 1 000 feet of heavy fence, made of wrought-iron pipe and fittings. The entire cost of the whole structure was $34 000, or $3 400 per million gallons capacity, which I believe is unusually low.

The advertisement for bids specified that bidders should submit their own plans and specifications for a 10 000 000-gallon reservoir, and there were practically no other limitations. The bids ran all the way from $27 000 for an earth reservoir to $55 000 for a heavy

* Consulting Engineer, Peoria, Ill.

concrete gravity section wall with a heavy bottom. The bid of the firm which employed me to prepare plans and specifications was $37 500. The firm was afterwards jewed down to $34 000, and then was awarded the contract. It completed the work in 100 days, giving bond to keep the reservoir tight for five years. The reservoir is apparently in excellent condition after two hard winters.

I had nothing to do with supervising the construction except that I went down occasionally to see what was going on. Some rather heroic tests were applied to the work during construction by the mayor of the city for which it was built. For instance, there was an embankment on the outside of the wall, and this embankment was raised to the height of the wall, at first back a little distance from the wall; then, when the concrete was only about seven days old, the space between wall and embankment would be filled in with water and the mayor then requested the contractor to dump the remaining part of the embankment, out of a bucket holding a yard and a half, into this water, so that he could see whether the wall was leaky. This test was continued all around the 950 feet circumference of the wall, and there was dampness on the other side in but five places, and in only one of those places did this dampness amount to a trickle, which did not exceed 3 drops per minute.

The wall was 3 feet in thickness at the base, 1 foot at the top, 15 feet high on the outside, and with a toe and heel which together made up a base of about 11 feet in width, forming a gravity section. I am unable to give from recollection many of the details as to the mixture.

I might mention, perhaps, as a matter of interest, the way in which the forms were built. They were built in 10-foot circumferential sections, the outside and inside forms fastened together. Eleven of these forms, making up a distance around the inside of 110 feet, were set up in the beginning, and the concrete was placed in the forms from the center toward the end in thin layers, so as to give as long a joint as possible. Then, as the work rose inside the form to the top of the wall, the center forms would be taken out and moved to the ends and the work continued in one piece all the way around until the wall met on the other side. The

bottom was 5 inches in thickness and was reinforced with quarter-inch rods spaced 6 inches center to center. They were roughly woven in mats about 25 feet square; one of these mats would be laid down and then filled with concrete. There was a top dressing of a half inch of cement, sidewalk finish, and of a richer mixture, over the bottom. I haven't been able to learn that there is any leakage.

A description of this reservoir was published in the *Engineering Record* of March 3, 1906.

Mr. W. C. Hawley.* Mr. President, I read a paper before this Association some years ago and detailed methods used to secure watertight concrete for the lining of reservoirs. I have had no experience in work such as has been described here, and I would only say that the work which I described in my paper has proven very satisfactory. The only difficulty appears to be in getting a watertight joint between the blocks of the concrete. On the last reservoir which we built we used a joint of asphalt, the concrete being placed against a sheet of steel one eighth of an inch thick, the steel sheet withdrawn before the concrete had set hard, and the space filled with asphalt or what is known as "mineral rubber." That has been very satisfactory, especially on the bottom; it is not quite so satisfactory on the slopes.

President Whitney. Wouldn't it be of interest to have some expression of opinion as to the probability of the steel reinforcement oxidizing in a reinforced structure? Mr. Hawley, we have just heard from you, but I should like to hear from you in regard to that matter. I would like to ask your opinion as regards the probability of the steel oxidizing.

Mr. Hawley. I think, Mr. President, that it depends very largely on how the concrete is placed; whether it is given a fair chance to get a good bond with the steel. The old idea of placing concrete so dry that it had to be tamped has passed away, and nowadays I think it is generally recognized as far better practice to make the concrete so wet that it must form a solid mass. That is what I have done. Our men in placing it wore rubber boots, and they would sink into the concrete nearly to their knees. We had splendid results.

*General Superintendent Pennsylvania Water Co., Wilkinsburg, Pa.

As a matter of interest in this connection I might say that a few years ago the abutments in a bridge on the Monongahela River were torn down. Any one familiar with the water of the Monongahela River knows that at times it is frightfully acid from the sulphur of the mines. When one of the stones was taken from its bed a steel cold chisel was found imbedded below the stone in the mortar of the joint. It had been there, I believe, for some thirty odd years, where this acid water certainly would have destroyed it if it could have reached it, but there was not a sign of rust on the chisel; it was perfectly bright and clean. I think that is pretty good evidence of the protection of steel where properly bedded in the concrete.

President Whitney. The question has been raised, Mr. Hazen, in regard to the probability of the steel reinforcement ceasing to have any special effect to strengthen a cement concrete structure eventually. What is your opinion in regard to that? What is your opinion in regard to the oxidization of the steel?

Mr. Allen Hazen:* I don't know that I have any special information on that, Mr. President.

President Whitney. You are supposed to have information on all subjects, Mr. Hazen.

Mr. Hazen. I was reading a description of reinforced concrete structures to hold water under pressure the other day, and this description told about some cracks that opened, and the steel, of course, prevented their opening very wide, and the cracks were calked, and they went on using the structure. Now, generally speaking, it is supposed that concrete will protect the steel from rusting, but it seemed to me in this case that the fact that a crack opened across the line of the steel necessarily meant that the concrete had slipped on the steel for a considerable distance on either side of the crack, and the steel crosses the crack and is certainly exposed to the water and is likely to rust away there just as it would do in the open. I wondered if the structure would not be destroyed after a while by the rusting away of the steel at these places even though it was generally protected. My feeling in building concrete structures to carry water under pressure has been to build them so that there would be definite cracks; or, in other

* Consulting Engineer, New York, N. Y.

words, build the cracks or joints and let those cracks open and protect them with some kind of an expansion joint.

In the case of the reservoirs at Watertown, N. Y., which were built of concrete backed up with loose stone fill — which was the only fill available — the watertightness depended on the concrete and on nothing else. The walls were built with some reinforcing, and the cracks in the joints that opened were calked in cold weather with oakum. That made the work substantially watertight, and it has so remained. The oakum is compressed in summer when the masonry expands, but in some way it seems to expand again in the winter, and keeps the crack reasonably filled so that it does not leak. It clearly does not do to calk the crack with cement, because, if this is done, in warm weather the corners spall off, and that leaves the crack in worse shape than it was before.

Mr. Walter H. Richards.* Mr. President, I remember twenty-five or thirty years ago there were plenty of engineers that were telling how to protect the iron in a water pipe with cement, — what to do for the protection of the iron in cement-lined pipes. There are a number of us who have found out we were mistaken since that time, and perhaps it may be so with reinforced reservoirs. We can't tell, but it occurred to me, while this paper was being read, that it would be very unfortunate if the reservoir should freeze over with any considerable thickness of ice. I presume that is amply provided against, but still it seems to me that there is a liability of its being unable to resist the ice pressure. I should say my prayers on a very cold night, anyway.

Mr. A. A. Reimer.† Mr. President, I thought that Mr. Fuller was going to give us his paper on waterproofing, so I was holding back what I wished to say. On the East Orange system we have two reinforced concrete structures that may be of interest in connection with this subject of waterproofing. One of the structures is a standpipe 50 feet high and 10 feet in internal diameter. The first 10 feet above ground is battered outside from 18 inches thick at ground level to 12 inches, the main shaft above this being straight 12-inch work. The roof is conical in shape, of 3-inch

* Engineer Water and Sewer Departments, New London, Conn.
† Superintendent of Water Works, East Orange, N. J.

concrete, covered with red tile for the sake of appearance. The Angus Smith process was used in waterproofing this structure, but unfortunately we have very little use for it, so have not been able to determine through the winter time — the most serious part of the year — the value of that waterproofing.

The other structure is a 5 000 000-gallon reservoir, with 12-inch walls strengthened by inclined buttresses 10 feet on centers. The reservoir wall has a heavy embankment on the outside, and in this wall the Angus Smith process was used as waterproofing. Evidences of leakage became apparent soon after the reservoir was put in service two and one-half years ago. We were never able to determine whether the leakage was from the joints or by means of general seepage through the walls because of the embankment outside, but we had collecting drains around through the embankment to drain the embankment, and during all the dry periods we had a large amount of water coming from those drains, proving that there was a serious leakage from the reservoir. The floor of the reservoir was leaking also, this being proved by the drains laid under the reservoir.

Because of these facts we took up the question of waterproofing this past summer, and after careful study I decided on the Sylvester process as being the most satisfactory for our purpose. We have treated the walls and floor of the reservoir with this process and have met with what might be called absolute success. There seems to be no seepage or leakage from the drains now, and we believe this condition will be permanent. If the work on the old Croton gate chamber may be cited as a criterion we should find our reservoir tight for many years to come. I speak of this as showing what repair work can be done with the Sylvester process.

Mr. Metcalf. How old is the Croton work?

Mr. Reimer. The dam is about seventy years old, but the waterproofing I speak of was done about forty years ago, I believe. The gate chamber is of brick.

Mr. Hazen. I don't know about that case. We have never experienced any difficulty in building concrete blocks so that they would not leak. I think if concrete is mixed wet, and is of the proper mixture and well worked down, the blocks themselves are tight. The only leakage we are afraid of is the leakage between

the blocks, or leakage from cracks that come where the length of a structure is so great that there are temperature cracks, or cracks from any other cause. Structures of some length, which may be as great as 100 feet, can usually be built and reinforced so that they will not crack. But with large structures cracks must always be expected.

Mr. Reimer. The Angus Smith process was used in the work as it was constructed, but the Sylvester process is what we used this past summer in making the structure finally watertight.

Mr. Brewer. I should like to know if anybody here knows about the Sylvester process, as to how long it has been actually proven effectual. While on my feet I might add that it seems to me that this question of the rusting of reinforcing rods buried in concrete is very different from the rusting of the wrought-iron shell of cement pipes such as many water-works men are used to and are sorry therefor. I don't think you can make a comparison between methods of doing one and the other. That ought to be borne in mind when you criticise the placing of rods in a concrete wall a foot or eighteen inches thick.

Mr. A. Prescott Folwell.* A reservoir which I built some years ago convinced me that in many cases all you need to secure imperviousness is well-made concrete; at least, that has been my experience. I have always borne the Sylvester process in mind, but never had occasion to use it. The reservoir referred to is about 200 by 300 on the water line, and the only application which I made, in order to make it tight, in addition to taking pains with the concrete, was to give it three substantial washes with neat Portland cement and water, each one being dried thoroughly before the next wash was applied. On filling the reservoir there was no leakage perceptible. We didn't take any account of evaporation or dew-fall, but marks were made on the side of the reservoir, — a very fine mark with a lead pencil, — and after watching for over a month we could see no perceptible rise or fall in the reservoir. There had been no rain, by the way, during that time, and how much effect the dew and evaporation had in counterbalancing each other I couldn't say. Another smaller reservoir, 1 500 000 gallons capacity, was built in the same way. That also

*Editor *Municipal Journal and Engineer*, New York, N. Y.

was, as nearly as we could ascertain, absolutely tight. We never found any leakage in that whatever.

I was somewhat proud of the larger reservoir for another reason, perhaps a little apart from the watertightness of the concrete, and that was, there was about three feet of an embankment on top of the bed rock at one end and it was all embankment at the other end. In other words, from half to two thirds of the reservoir was excavated out of rock, and the other end of the same reservoir was on dirt having a depth of 10 or 15 feet, possibly more, in thickness above the rock; but at the point of junction between the earth bank and the rock no cracks appeared in the concrete lining, so solidly had the embankment been compacted. The concrete was mixed 1: 2½: 5, of broken limestone. The pressure was about twenty feet head. A large number of analyses were made of the broken stone and sand to determine what percentage of the various ingredients which were used in the mixture should be taken. As I say, we got apparently a very tight concrete and one which did not crack. The cement wash was very thin and did not form a coating to peel off later.

The reservoir has been in use two or three years now and I believe has never leaked at all. I have made a great many smaller tanks, giving the same wash of Portland cement and water, and if there was any trouble it was because of cracking and not of perviousness.

Mr. F. L. Fuller.* Mr. President, I think concrete reservoirs are apt to improve in tightness with age and use, even if no interior surface application is made. Much, however, depends upon the quality of the concrete and the care with which it is placed.

I think a free use of very finely ground neat Portland cement, mixed with water to about the consistency of paste, thoroughly applied with a brush on the inside surface, is very effective. No doubt by allowing the original inside surface to be rather rough and, after removing the centering, putting on a thin, thoroughly troweled plaster coat of neat, or perhaps 1 to 1 Portland cement over the sides and bottom and then adding the brush coats, a reservoir can be made practically watertight. The Wellesley concrete-covered reservoir, built under the supervision

* Civil Engineer, Boston, Mass.

of F. C. Coffin, in 1897, was tested in January, 1907, by closing the outlet valve into the distribution system for the space of twenty-three hours, and no drop took place in the water surface, the reservior being nearly at high-water level.

A number of other concrete reservoirs tested by me while new showed some leakage. No doubt a portion of the drop in the water surface was due to the absorption by the dry concrete of a certain amount of water. By the application of brush coats on the bottom and side, or in some cases of a thin plaster coat on the bottom, before the brush coat was put on, the leakage was materially reduced. After a reservoir has been put into service, it is, of course, difficult to test it unless it is one of a set which can be temporarily disconnected from the distribution system, but I am of the opinion that most of these concrete reservoirs would be found substantially tight.

It is often advisable to place an underdrain beneath a reservoir to take away the ground water in the soil where the reservoir is located, thereby relieving the bottom of an upward pressure, due to the level of the ground water above the reservoir bottom.

During dry weather the amount of ground water decreases and may fall below the level of the bottom of the reservoir. It then furnishes a means of measuring the amount of leakage from the reservoir, if any. In two instances, where used by me there has been no flow of water from the underdrain during the dry season, indicating the tightness of the reservoir.

I have noticed in a section of cement-lined water main, newly cut out, something in the nature of a thin, transparent slime adhering to the surface of the cement forming the inside of the pipe. The same formation may exist on the bottom and sides of a concrete reservoir, and might be seen, provided the reservoir could be emptied suddenly and inspected before the surface had time to dry. This slimy coating may have a decided tendency toward making the surface impervious to water.

Concrete to be impervious to water when set should be mixed quite wet and after being dumped should be worked into place and manipulated so as to make as nearly as possible a solid mass with no voids. This is impossible with dry concrete. Wet concrete should be worked with tools similar to a spade or a thin

and rather narrow chisel-shaped piece of iron or steel connected to a straight handle, rather than the ordinary flat-cast-iron tamper having a considerable area.

The agitation with these tools tends to dispel air bubbles and to settle and thoroughly mix the aggregates till the mass is practically solid.

The Sylvester method or process of waterproofing does not appear to have been largely used in this vicinity. In the only instance with which I am familiar, it did not prove very successful.

Mr. Allen. Some years ago I put in a system of sewers for the military post at Fort Supply, I. T. As there were no roads, and as some of the trenches were very shallow, a number of flush tanks were almost entirely above ground. They were built of brick with a $\frac{3}{8}$-inch coat of natural cement plaster on both inside and outside painted with neat cement grout. Several of these persisted in seeping to a slight extent. Portland cement was not available, so I used the Sylvester process on the inside of those that gave trouble, and it was entirely successful.

Mr. McKenzie. Mr. President, I have had a similar experience to Mr. Fuller's with reference to washing reservoirs with neat Portland cement, applied with a brush. The year before last we built a dam some 16 feet high, using iron beams for reinforcement, and applied Portland cement wash to the face of the walls for waterproofing it, two coats, to make it absolutely tight.

Last year we built another one, 19 feet in height, and the wash was applied with a brush, — neat Portland cement, — and it is absolutely tight.

I am very glad to learn that the Boston engineers have found out that dry concrete doesn't make a tight wall. Only a few years ago the Boston engineers practiced making concrete very dry, — so dry that it couldn't possibly be consolidated. But I understand that they know now that they can use it wet.

Mr. Brewer. Referring once more to the discussion as to the life of steel in a concrete structure built for holding water, I might add that that phase of the proposition furnished us very little anxiety. The following suggestions may, however, be of value:

In the Waltham reservoir the steel was thoroughly coated with and imbedded in a very alkaline semifluid substance which has

since become practically an impervious rock. There is no space around the metal for the accumulation of rust, or, to put it in another way, the space needful for oxidization is lacking. We must, therefore, conclude that oxidization cannot proceed very far with the steel properly embedded in the concrete.

If we accept the most recent explanation of the rusting process, that corrosion is always due primarily to electrolytic action, we may summarize as follows: Oxidization cannot occur to any extent, because of:

First. The alkalinity of concrete.

Second. Lack of space.

Third. Limited supply of water.

Fourth. Limited supply of oxygen.

RECENT IMPROVEMENTS TO THE WATER WORKS AT PEABODY, MASS., INCLUDING PUMPING PLANT AND DISTRIBUTING RESERVOIR.

BY FRANK A. BARBOUR, CIVIL ENGINEER, BOSTON, MASS.

[*Read September 11, 1907.*]

The Peabody water works were originally purchased from the Salem Aqueduct Company, one of the oldest in the country. The history of these works begins in December, 1796, the year the Boston system was introduced, when a meeting of subscribers of the Salem and Danvers Aqueduct Company was held at the Sun Tavern, Salem, Mass. At this meeting a committee of three was appointed to procure an act of incorporation, to make all contracts for logs and boring of same, and to contract for land through which the aqueduct was to pass. The necessary funds for starting the work were procured by issuing one hundred shares of stock at $40 per share. A petition for incorporation was presented to the General Court in January, 1797, and an act of incorporation was signed by Gov. Samuel Adams on March 9 of the same year. Work was immediately begun, the pipe line consisting of logs with a bore of 3-inch diameter, and by August the work was so far completed that the directors were authorized to dispose of the privilege of drawing water from the aqueduct for a term not exceeding one year, under such terms and restrictions as they should judge proper. The rate for a family having one post was $5 annually, to be paid semi-annually.

In 1804, after the company had expended $44 000 on the works, it was found that the supply through the 3-inch log was inadequate, and it was ordered that a new log be laid for the aqueduct with a bore of not less than 5 inches.

The first iron pipe, which was 6 inches in diameter, was laid by the company in 1834. In 1850 a 12-inch iron pipe was laid from the source of supply to Federal Street in Salem. In 1866 this 12-inch pipe was extended to a point opposite the Market House in Salem. This 12-inch iron pipe is to-day the means of supplying

a small service district in Peabody. After 1852 all extensions were made with cast-iron or cement-lined iron pipe instead of logs. In 1865 a 16-inch cement-lined pipe was laid from the reservoir to Federal Street, Salem. To-day this pipe is one of the principal distributing mains of the town.

In 1873 the town of Peabody purchased the works and franchise from the Salem Aqueduct Company for $125 000. At the time of the purchase one hydrant, located at the Square and attached to the 12-inch pipe, was the only fire protection afforded to Peabody by the system.

Originally the works were planned to furnish Salem and Peabody with water by gravity from Spring Pond. After their purchase by the town, higher pressure being desirable, a pumping station was constructed at the corner of Foster and Washington streets, the water being drawn from the 16-inch gravity main and, after passing through the pumps, being again returned to this same main. In 1882 a standpipe 60 feet in diameter and 23 feet high was erected on Buxton Hill, with its high-water mark at elevation 180 above mean low tide.

The pumping plant consisted of two Worthington pumps, one pump being a horizontal duplex, compound condensing type, rated at 2 500 000 gallons capacity, the other a horizontal duplex simple type of 2 500 000 gallons capacity. The boilers were two in number, 15 feet long, 6 feet diameter, rated capacity 95 horsepower, and when operating carried about 65 pounds steam pressure.

In 1902 the consumption had increased to a point where the capacity of the pumps was not sufficient to fill the standpipe without running well into the night, and the water stored in this way was so far depleted by the night draft that but little remained at the time of starting the pumps the next morning. It was therefore evident that pumps of greater capacity were needed and, if the pump run was to be limited to a reasonable number of hours per day, that a larger standpipe or a reservoir, capable of holding a supply sufficient for the town during the time the pumps were not in operation, must be provided. It was accordingly recommended that a pump of 5 000 000 gallons daily capacity be installed in a new station, located at the source of supply, thus

doing away with the long pipe line between the supply and the old station which, while originally a pressure main, had, under the increased draft, operated of late years as a suction pipe.

It was further decided to construct a circular masonry reservoir on Lookout Hill, of 2 500 000 gallons capacity, with its high-water mark at elevation 220, or 40 feet above that of the old standpipe, and to connect this reservoir with the distribution system by a 20-inch supply main 10 000 feet long, extending to the corner of Foster and Washington streets, the location of the old station.

It is intended in this paper to briefly describe the pumping plant and reservoir which, while involving nothing of particular merit, are perhaps of sufficient interest to justify their being made matters of record. In the experience of the writer it has often appeared that while descriptions of large works can be readily found, smaller plants have been more or less neglected, and it is often difficult to obtain suggestive plans and information of the class of work demanded for a community of ordinary size.

Incidental to these improvements in the distribution system, some work was done in bettering the quality of the supply. Around Spring Pond numerous small cottages had been located, and there were evidences that the pollution of the water would rapidly increase unless precautionary measures were taken. Application was accordingly made to the State Board of Health for the establishment of sanitary regulations governing the watershed, and, in addition, land was purchased for a depth of 200 feet from the shore line, thus requiring the removal of all cottages to a considerable distance from the pond. The opportunity to invoke the powers of the Board of Health in the protection of watersheds, by the establishment of definite regulations, is believed to be one of the most valuable provisions in the sanitary laws of the state. While the final results depend on adequate supervision and inspection, these rules focus attention on the necessity for taking particular care in the case ot such watersheds as those from which the Peabody supply is drawn.

Before entering upon a description of the pumping plant, it may be well to briefly consider the records of consumption during the past ten years in Peabody. These are most abnormal in the relation of manufacturing and domestic use, and are of interest

in indicating how rapid may be the increase in the demand for water in a town depending on one particular industry which is, for the time, enjoying unusual prosperity. Tanneries and glue works constitute the local industry and use large quantities of water. In addition to the amount drawn from the town supply — 879 000 gallons per day — probably as much more is obtained from private sources.

The following table shows the water consumed each year in the pumping district since 1895:

TABLE No. 1.

Year.	Gallons Pumped.
1895	330 050 880
1896	339 682 860
1897	340 535 737
1898	353 418 735
1899	415 644 841
1900	377 248 159
1901	411 283 296
1902	456 849 304
1903	544 332 291
1904	611 195 167
1905	639 508 600
1906	691 527 606

From 1895 to 1906 the water consumption increased two hundred per cent., while the population increased by twenty-five per cent. The manufacturing consumption during this period increased two hundred and fifty per cent. The per capita consumption in 1895 was 87 gallons; in 1906 it was 145 gallons. The manufacturing consumption in 1901 was 32 gallons per capita; in 1906, 67 gallons.

The following table shows the increase in manufacturing consumption, domestic and public consumption and leakage since 1901:

TABLE No. 2.

Year.	Total Average Consumption. Gallons per Day.	Manufacturing Use as Measured by Meters. Gallons per Day.	Domestic and Public Use and Leakage. Gallons per Day.
1901	1 200 000	354 000	846 000
1902	1 315 000	439 000	876 000
1903	1 520 000	620 000	900 000
1904	1 800 000	694 000	1 106 000
1905	1 750 000	736 000	1 014 000
1906	1 895 000	879 000	1 016 000

The increase in the column under domestic and public consumption and leakage in 1904 was due to increased leakage from the effect of the higher pressure from the new system.

The Sunday and week-day consumption in 1906 is estimated as follows:

Sunday.	6 A.M. to 6 P.M. =	565,000 gallons per day
	6 P.M. to 6 A.M. =	425 000 ,, ,, ,,
Week day.	6 A.M. to 6 P.M. =	1 510 000 ,, ,, ,,
	6 P.M. to 6 A.M. =	530 000 ,, ,, ,,

The consumption in 1906 may be divided as follows: For mainfacturing uses, 67 gallons per capita; for domestic and public uses, 35 gallons per capita; and unaccounted for, including leakage, under-registration of meters, etc., 43 gallons per capita.

The consumption between the years 1900 and 1905 increased 41 per cent., and in the latter year it became apparent that no time should be lost in obtaining an additional source of supply. The town had already obtained the right to the waters of Suntaug Lake, and the utilization of this source was accordingly recommended, construction being begun in the summer of 1905. This lake is situated at a higher level than either Spring or Brown's ponds and the addition of its waters to the old source of supply by gravity was, therefore, possible. The pipe line consisted of 20-inch and 24-inch pipe, laid in trench of ordinary depth for a distance of 15 400 feet, up to the point where the ridge surrounding Suntaug Lake was encountered, the surface of which stands some forty feet above the hydraulic grade line of a gravity conduit. Through this ridge it was accordingly necessary to tunnel. This section of the work, 1 600 feet in length, proved most difficult, and the time necessary for its completion considerably greater than esti-

mated, water not being run through the tunnel until July 1, 1906. In the meantime the abnormal increase in consumption had continued, and during the winter of 1905–1906 the condition of the ponds provided a good object lesson that from a given water-shed and storage capacity only so much and no more water can be obtained. The records which have been kept between the years 1903 and 1906 indicated that the Sudbury records were closely applicable to the Peabody conditions.

Below Spring Pond an intake reservoir of 25 000 000 gallons effective capacity extends northerly for a distance of 3 000 feet, and at its lower end the new pumping station was located. This reservoir constitutes the collecting point of all the different sources of supply, and if in the future filtration should be required it will prove a favorable location for the necessary plant, and the pumping station will be in the right position for the handling of purified water.

From the reservoir a 24-inch pipe was laid to a concrete pump well underneath the station. Double screens of standard design, with catch baskets attached to the bottom section, were located in a screen-well also under the station.

The pumping station is a brick structure with concrete foundations and includes coal-shed, boiler-room, machine shop, engine-room, and office. Emphasis was laid on good head room below the engine-room floor in order to make all piping and auxiliaries easily accesssible.

The pumping plant consists of two 100-horse-power Stirling boilers and a 5 000 000-gallon triple-expansion duplex Worthington pump with high-duty attachment.

The boilers are standard Stirling construction with three banks of tubes connecting the steam drums with the mud drum and a Niclausse superheater suspended between the middle and rear banks of tubes. The boilers contain 990 square feet of heating surface and 28 square feet of grate surface and are designed for 160 pounds working pressure.

The superheater is planned to superheat the steam 100 degrees above the temperature due to a pressure of 150 pounds. It is practically the same as a Niclausse boiler element, and is so arranged by dampers operated from outside the setting that the

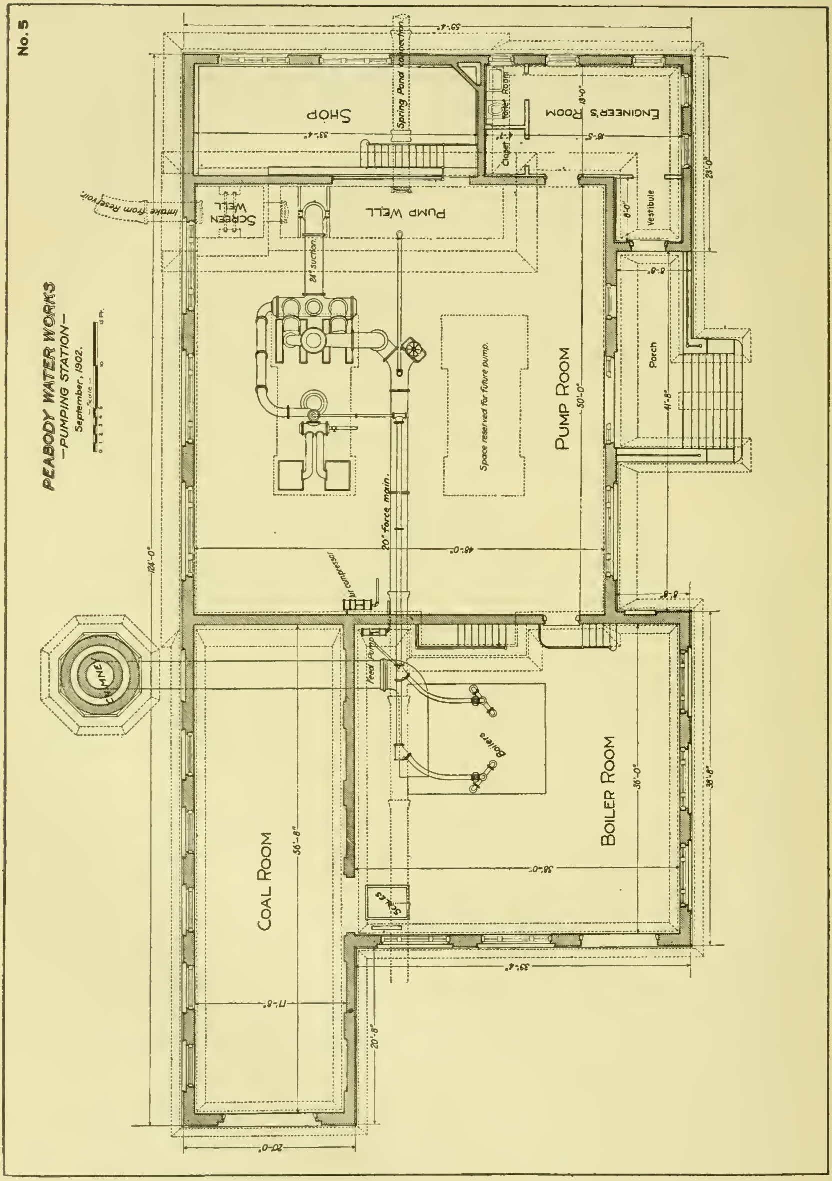


Fig. 1. Plan of Pumping Station.

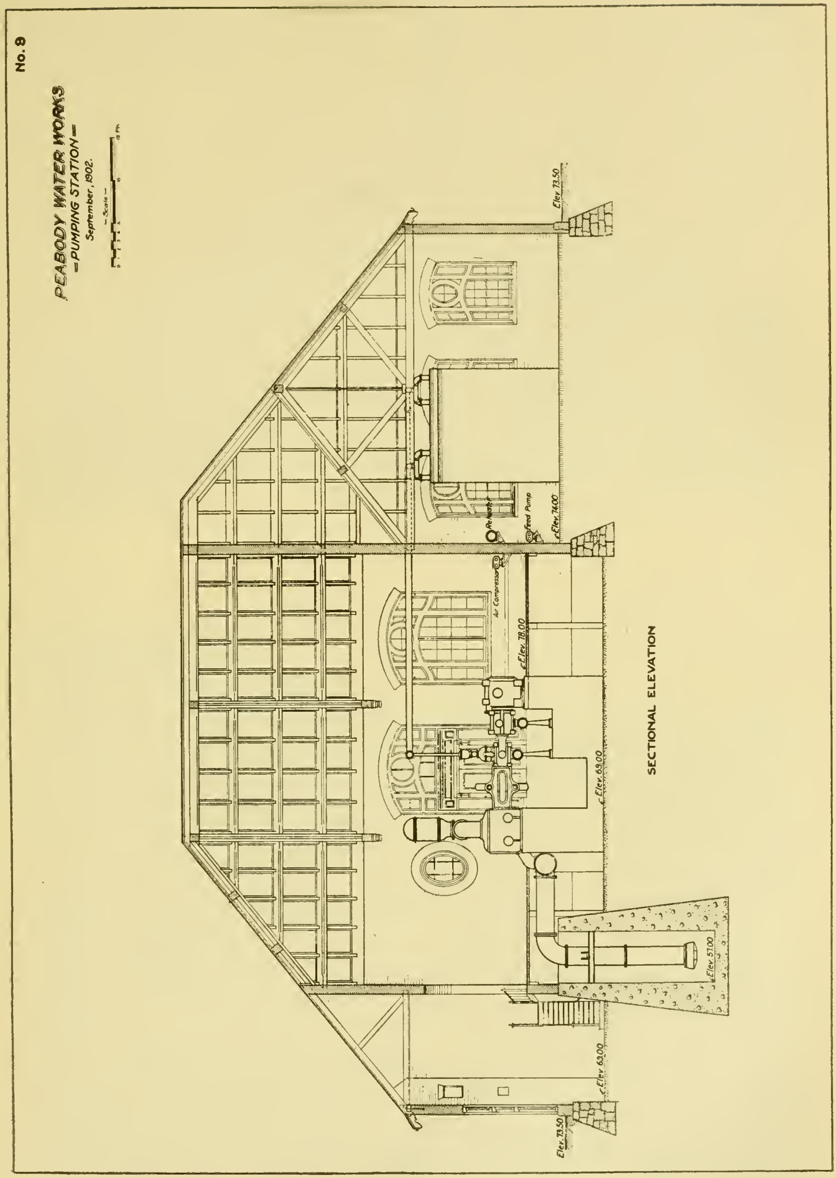


Fig. 2. Longitudinal Section of Pumping Station.

gases can be by-passed around the superheater and thus the amount of superheat controlled. Owing to the location of the superheater it is practically indestructible and does not require flooding when steam is not circulating through it.

The engine, as already stated, is a triple-expansion Worthington duplex, with high-duty attachment located between the high-pressure and water cylinders. The diameters of the steam cylinders are 12, 20, and 34 inches, and the nominal stroke 24 inches. The water plungers are 18 inches in diameter, and the average pressure pumped against is 165 feet.

Reheaters are placed between the high and intermediate cylinders and between the intermediate and low-pressure cylinders. The steam cylinders are jacketed with steam at boiler pressure, which also serves to heat the tubes of the reheaters between cylinders. The condensation from this jacket space is collected below in a tank having a ball float which controls the steam supply of a 3 × 2 × 2-inch pump, which takes the water of condensation from the tank and returns it to the boiler.

In the exhaust line between the low-pressure cylinder and the surface condenser is a closed heater having 30 square feet of heating surface. For boiler feed, water is forced through this heater by the delivery line pressure to a $4\frac{1}{2} \times 2\frac{3}{4} \times 4$-inch boiler feed pump, at a temperature slightly below the temperature of the main engine exhaust. The feed pump then forces it through a 15-square-foot closed heater which is heated by the exhaust from the feed pump, Westinghouse air compressor, and the jacket pump. The feed is thus put into the boiler at a temperature of approximately 200 degrees.

Located in the suction pipe of the main engine is a surface condenser of 228 square feet surface. A duplex air pump, having 9-inch plungers and 6-inch stroke, driven by the motion of the main engine, takes the water of condensation from the condenser and discharges it to the sewer.

Each cylinder of the engine has four valves operated by the Worthington semi-rotative valve motion, the feature of which is that there are no trips or dash pots, all motion being positive.

An early cut-off is made possible by the use of the high-duty attachment. This well-known Westinghouse device consists of

FIG. 1. FRONT VIEW, PUMPING STATION.

FIG. 2. DRY MASONRY OUTSIDE WALL AND DRAIN.

compensating cylinders and an accumulator, by means of which the surplus energy available at the beginning of the stroke is stored up and liberated at the latter end during the expansion of the steam. The accumulator has an air cylinder 17¾ inches in diameter and a water plunger 4¼ inches in diameter, both of 30-inch stroke. The compensating cylinders have plungers 4⅜ inches in diameter, and the system is supplied by duplex pump having ¾-inch plungers and 4-inch stroke, driven by the motion of the main engine. These pumps receive water from the delivery main or tank that is supplied with clean water from the air pump delivery. A 9½-inch Westinghouse air compressor supplies the air for this system.

No attempt was made to determine the efficiency of the boilers, the contract requiring a duty per 100 pounds of dry Georges Creek or equally good coal burned without allowance for ash, the work being done determined by the water pumped into the reservoir, and the pressure obtained by the reading of a gage on a force main plus the distance from the center of this gage to water in pump well. Under these conditions the contractor guaranteed a duty of 130 000 000 foot-pounds.

The following table gives the principal results of test:

Principal Results of Test of Peabody Pumping Plant.

Date of test	June 20, 1904
Duration of test	10 hours
Grate surface	28 square feet
Boiler heating surface	990 square feet
Diameter of chimney	39 inches
Height of chimney	100 feet
Steam pressure in boiler	156 pounds
Draft	0.242 inches
Temperature of fire room	73.4 degrees
Temperature of steam at boiler	423 degrees
Temperature of flue gases	422 degrees
Temperature of feed water	192 degrees
Fuel burned	2 380 pounds
Moisture (per cent.)	0.0094 per cent.
Dry coal consumed	2 357.6 pounds
Steam pressure at throttle	152.9 pounds
Steam temperature at throttle	404 degrees
Superheat	44.33 degrees

Average length of stroke	24.62 inches
Total number of revolutions	22 031
Displacement per revolution	14.303 cubic feet
Total head	163.99 feet
Slip of pump	1.51 per cent.
Rate of pumping per twenty-four hours	5 671 965 gallons
Duty per 100 pounds dry coal	134 607 000 foot-pounds

This relatively high duty for such type of pump working under the above-outlined conditions may be largely attributed to the superheating of the steam.

The test was started and stopped without drawing the fire from under the boilers. Whether ten hours is long enough to nullify the personal equation in the different observations, and particularly in judging the depth of coal on the grate at start and stop, is here, as in all such tests, worthy of consideration. In the writer's opinion, moreover, tests of municipal plants should be made on as practicable a basis as possible and as nearly in accordance with the actual running conditions as may be arranged. One of the elements not covered by a ten-hour test is the coal used in banking. Recently, in a plant where gas producers are now being installed, the writer called for bids from builders of both steam and gas engines, requiring, on an equal basis, a guarantee of duty determined by a three-days' test, the engine to run 8 hours and fires to be banked 16 hours each day, and the plant being charged with all coal used in banking and all standby losses. Such a test, it is believed, will eliminate to a considerable extent the results of expert firing and the relation of personal error in observation. It also expresses the relative expense of banking in the different types of apparatus.

The station records of the Peabody plant are of interest. The duty, allowing 2 per cent. slip, on basis of total coal burned in 1905, was 77 900 000 foot pounds, and in 1906, 81 500 000 foot-pounds. These figures are relatively 58 and 61 per cent. of the test duty. It is interesting to note that at Attleboro, with a compound crank and fly-wheel engine and a test duty of 119 000 000, the station duty, including banking, is 61.5 per cent. of the test duty, and the experience of the writer is that the working duty will average about 60 per cent. of the duty

obtained in ten-hour tests. The duty at Peabody, without taking into account the coal used in banking, or on the same basis as test, is about 82 per cent. of the test duty. In Attleboro the equivalent figure is 85 per cent. The coal used in banking at Peabody, with the engine running ten hours, is about 28 per cent. of the total coal. At Attleboro, with a seven-hour run of the pumps, exactly the same percentage of the total coal is used in maintaining the fires during the time when the engine is not running.

Few repairs have been necessary, and the engine is a smooth, quiet running piece of mechanism. Such a type of pump, however, requires more attendance, particularly in starting, than a crank and fly-wheel machine, and this is also true of the water tube boilers as compared with horizontal tubular, except where the former are operated in an extensive battery. The limited heat storage in a single water tube boiler demands more constant attention, which is not justified by the quicker steaming capacity in a station where the load is constant. Therefore, while both the test and station duties obtained are good, the labor account is higher than would be necessary in a plant with horizontal tubular boilers and a crank and fly-wheel pump.

Lookout Hill, chosen for the site of the reservoir, is one of the historic spots in the Revolutionary history, of which many are found in the neighborhood of Salem. From its prominence as a vantage point it early gained its name. When, in 1692, John Proctor and his wife, accused and found guilty of witchcraft, were hanged on the neighboring hill to the east, a group of interested spectators probably pushed and crowded for seats on the boulder which is now the special care of one of the historical societies, and to preserve which the reservoir had to be thrown as far to the south as possible. Again, tradition has it that when the *Chesapeake* and *Shannon* met in their historic fight a party of patriots gathered on this eminence and anxiously watched the course of events.

This hill, which was the only one available with the elevation required for a reservoir, in formation was, roughly, an inverted cone of ledge covered with a slight depth of earth. The steep approach rendered the transportation of supplies difficult and expensive and made it necessary to utilize, as far as possible, the materials encountered in the excavation in the construction of the reservoir.

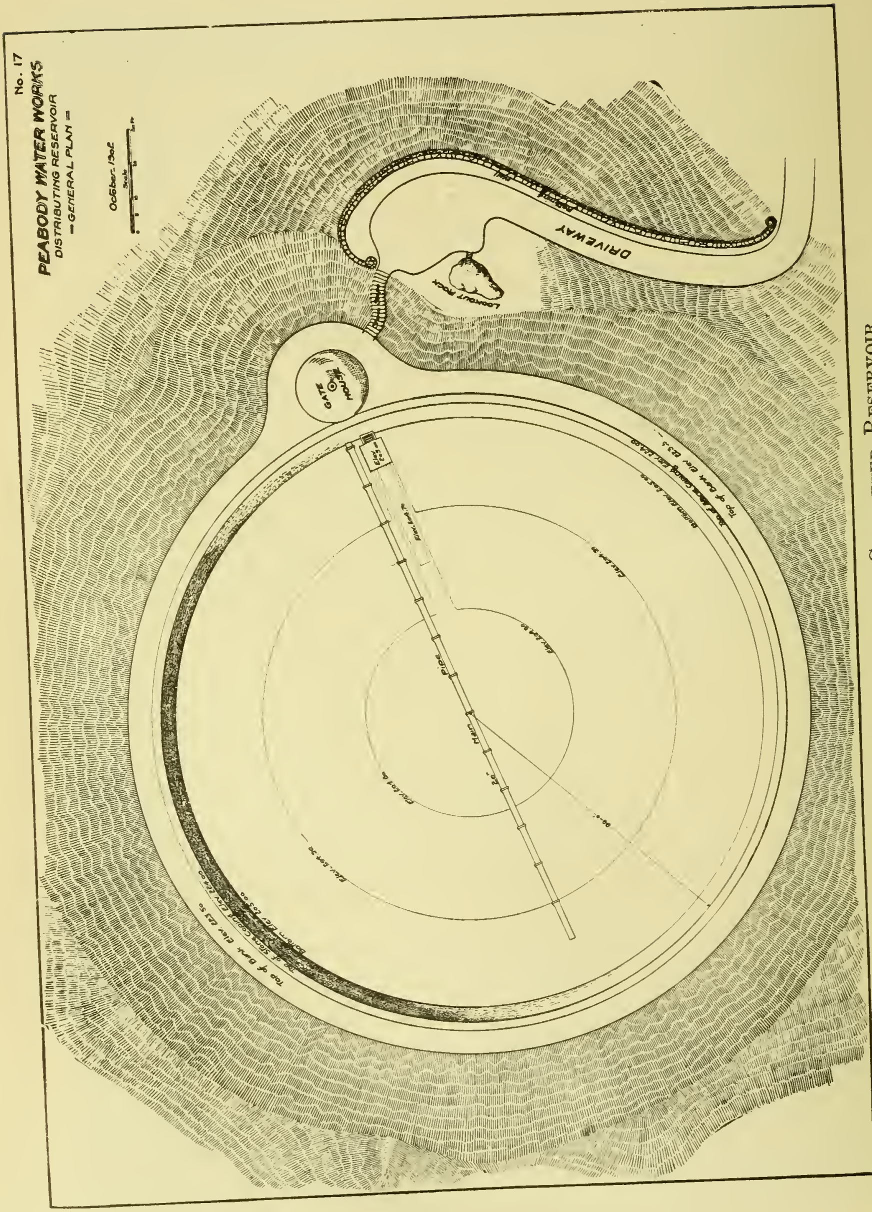


FIG. 3. GENERAL PLAN OF COMPLETED RESERVOIR.

Fig. 1. Excavation of Ledge, and Construction of Outer and Inner Walls.

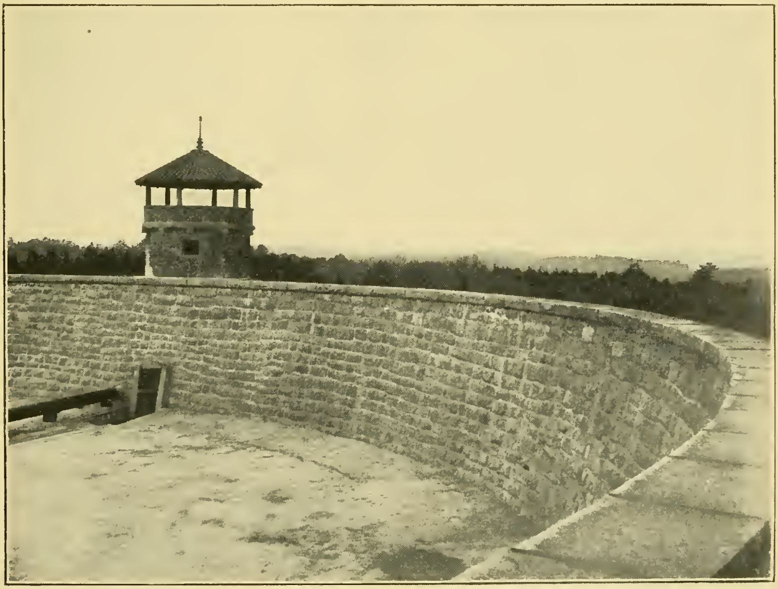


Fig. 2. Finished Wall, Inlet Pipe, and Outlet Screen.

The leveling of the cone required the removal of about 5 000 cubic yards of earth and 6 000 cubic yards of rock. The additional earth necessary to back up a masonry lining in the ordinary way could not be economically obtained. At the same time the desirability of leaving the hill in as sightly a condition as possible made it necessary to dispose of the rock excavation without obtrusive spoil banks.

It was accordingly decided to build a dry wall with the excavated rock, laid with interior vertical face on a circle, constructing this wall by merely moving the rock from the place of its excavation by derricks and placing it with only sufficient care to prevent subsequent settlement. Inside of this dry masonry wall it was proposed to build a wall laid with Portland cement mortar, using the stone excavated in the construction of the reservoir, but, with the idea that the stone might not come out in such shape as to permit its use in this way provision was made in the specifications for an alternate plan of lining the dry masonry wall with a wall of Portland cement concrete. In this work, as in all recent work of the writer's, the cement has been furnished by the contractor but paid for separately by the barrel. It was soon found that the nature of the rock, which was a trap and which broke in all manner of shapes and sizes, made impossible the construction of a suitable wall of it, and by arrangement with the contractor it was finally decided to build a thin face wall of rough granite ashlar, obtaining the stone by splitting boulders, which were found in large quantities on the hill near the reservoir, and placing between this granite facing and the dry wall a concrete composed of natural cement and aggregate in the proportion of 1 part cement, 2½ parts sand, and 5 parts crushed stone. The use of the granite facing obtained a structure more pleasing in appearance than would be possible with concrete, did away with the necessity for all form work, and by using natural cement in the backing of concrete, which effected a saving of $1.00 per cubic yard, did not involve much increased cost.

The dry wall, which was placed on the outside to a rough slope, was covered with the earth obtained in the excavation of the reservoir to a depth sufficient to utilize the material available. Thus in this reservoir the construction includes an inner lining, and back of this, for stability, a loose rock filling covered by a coating of earth.

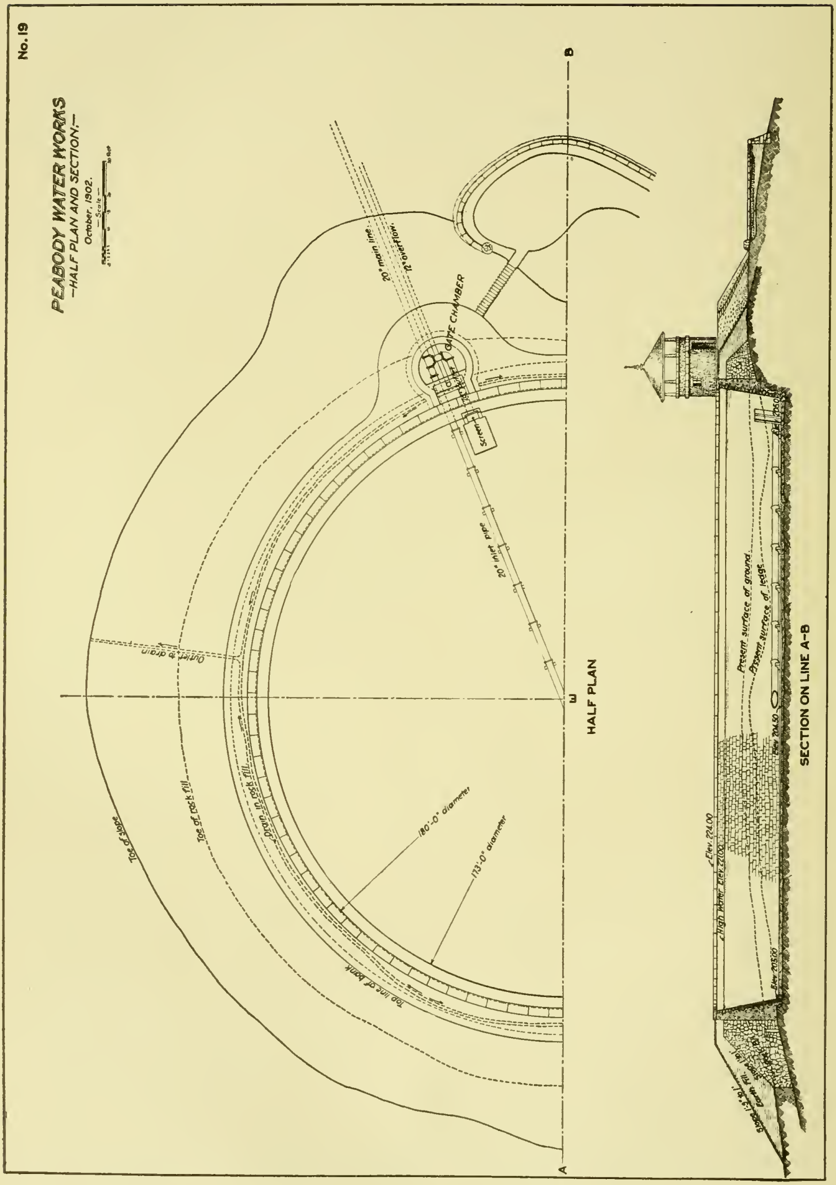


FIG. 4. HALF PLAN AND SECTION OF RESERVOIR.

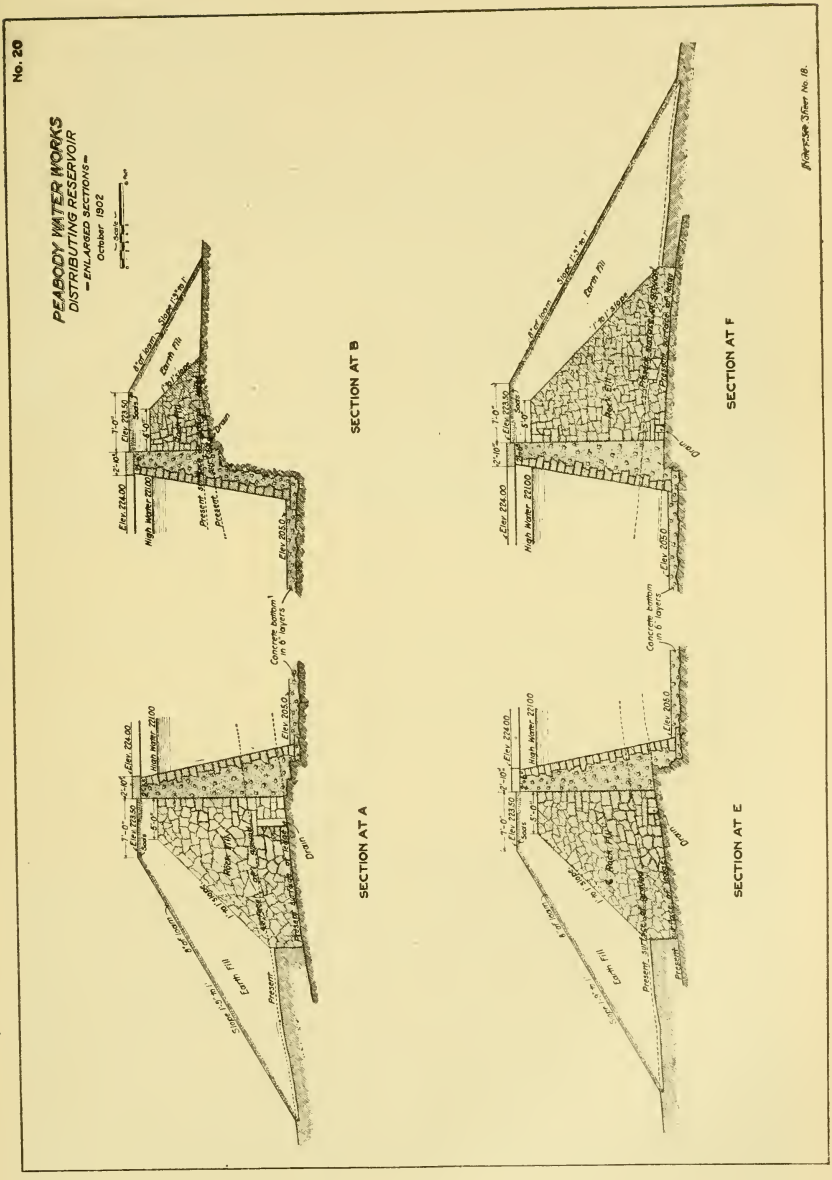


FIG. 5. SECTION OF RESERVOIR WALLS.

Such construction is contrary to the usual method of placing against the lining the most impervious material obtainable. The danger with the scheme adopted lay in the fact that any leakage through the inner wall might be temporarily impounded by the outer layer of earth until it had collected to a point where the earth would be washed away. To prevent this the ledge was stripped as a foundation for the dry wall and on this foundation, and entirely around the reservoir, following the natural contour of the rock, a masonry drain was constructed with its outer wall laid in cement, thus providing a cut-off for all water which might seep through the inner lining. Outlets through the bank to the outside of reservoir were provided at two points and all leakage was led out where it could be seen and measured. Actually this precaution has been of little or no value as the leakage has been practically nothing, one outlet being entirely dry and the other at times showing a dribble which probably comes from a spring encountered in the excavation of the ledge and covered by the concrete floor.

The ledge was very broken and seamy and the bottom of the reservoir was formed of two layers of concrete, the first of natural cement mixed 1: 3: 6, used largely to level up the uneven rock; the upper of Portland cement concrete, mixed 1: $2\frac{1}{2}$: 5 and troweled to a hard granolithic surface.

The reservoir was enlarged from the original plan to a capacity of about 3 200 000 gallons. The total cost was about $48 000, or 1.5 cents per gallon of capacity. The price paid for rock excavation, which included the building of the dry wall, was $2.25 per cubic yard. The actual cost of drilling was 37 cents per cubic yard; of dynamite, .09 cent per cubic yard; of barring out, breaking up, and removing to the wall, 1.05 cents per cubic yard; and of placing in wall, including construction of inner face, 34 cents per cubic yard. These figures do not include any allowance for rent of machinery.

The 20-inch pipe connecting the distribution system with the reservoir branches in the gate chamber,— one branch, the inlet, extending across the reservoir; and the other, the outlet, just through the wall. By check valves the water is compelled to traverse the reservoir and to pass through screens set over the outlet pipe. At times some sediment is settled out of the water. Gates are also provided in the gate chamber to shut off either

FIG. 1. GATE HOUSE AND LOOKOUT BOULDER.

FIG. 2. RESERVOIR IN SERVICE.

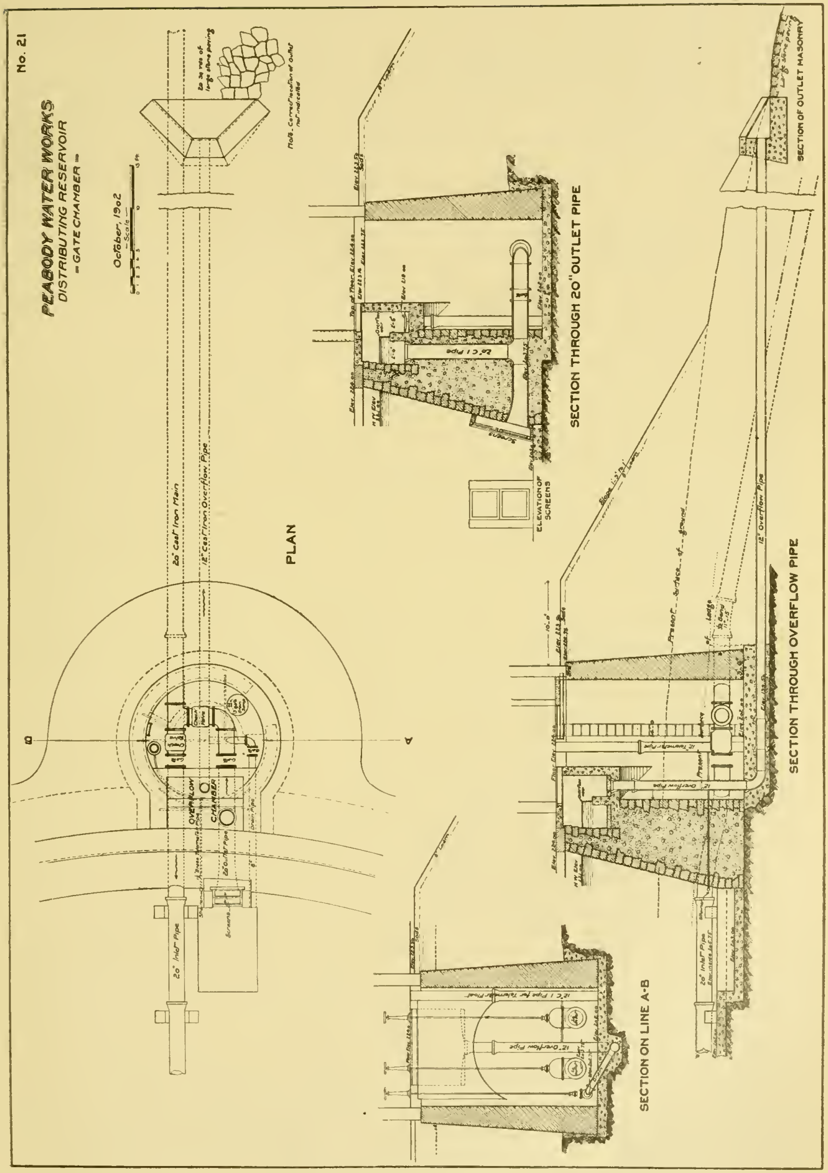


Fig. 6. Details of Gate Chamber.

branch and permit examination of the check valves. A 12-inch pipe makes possible the draining of the reservoir and the blowing off of any accumulated deposit.

The gate chamber is a dry well 13.5 feet in diameter, connected with, but outside the wall of, the reservoir, and containing, besides the various valves, the pipe for the float of the Winslow recording instrument. In this chamber, supported by an arch thrown across on a chord of the circle, is an overflow weir, connected on the reservoir side, by a pipe laid in the wall, with the water in the reservoir, and on the outlet side, by a 12-inch pipe, leading to the blow-off pipe in such a way that at all times there is a free vent, which cannot be closed, for any water which passes the crest of the weir set at the desired maximum water line. Numerous accidents have occurred in reservoirs not provided with overflows, and these even where the water is pumped. The design herein described, while supplying a free outlet, does not weaken the wall nor place the overflow in such position that it will be frozen in winter.

The gates are provided with extension stems and are operated at the level of the ground in a circular masonry gate house constructed over the gate chamber. Above this gate house is an observation gallery open to the public at all times, surmounted by a conical roof covered with red Spanish tiling. The gate house is constructed of stone obtained in the excavation, with seam faces colored by the iron contents. The view from this gate house, which extends over a wide stretch of country to the north and along the shore from Boston Light to Eastern Point at Gloucester, is well worth the trouble of climbing the hill to the reservoir. The town of Peabody owns a considerable amount of the adjoining land which, in its topography and situation, may well form the basis for some future park system. With these conditions in mind the committee believed that the construction of this gate house and observation gallery was justified, a fact which has been proved by their popularity as an objective point in the recreation wanderings of the citizens of Peabody.

Mr. H. F. Walker was chairman of the special committee under whose authority the work was carried out, and Mr. A. N. Jacobs is superintendent of the water works. The C. E. Trumbull Company were the contractors for the reservoir.

CAST-IRON PIPE SPECIFICATIONS.

BY WILLIAM R. CONARD, BURLINGTON, N. J.

[*Read September 12, 1907.*]

This article would perhaps have been more appropriately called "Some Possibilities of Cast-Iron Pipe Specifications," for it is only intended to show what may be done.

Let us suppose that the various manufacturers of cast-iron pipe have been thoroughly canvassed for the dimensions of their various pipe patterns and it is found, for example, that nearly if not quite all of them have a size of fixtures that will make a pipe of dimensions that coincide exactly or very closely with those shown in the present New England Water Works Standard Specifications for Class "F," which we will say is for a pressure head of 300 feet. This we will consider is about the maximum head that will for ordinary water service be used.

Again, taking these dimensions, we find that for a given class of pipe we have nominal inside diameters of 6 inches, 8 inches, 12 inches, 16 inches, etc. The nominal diameter being also the actual diameter for the heaviest class, it gives the full carrying capacity of that size of pipe. We now wish to provide for a lighter class of pipe for a less head; we still maintain the outside dimensions of bell and body and same bell opening, and increase the internal diameter of the barrel, resulting in less weight of iron in the pipe, and a slightly increased carrying capacity, — this of course being more noticeable on the pipe of larger diameters, due to their heavier walls.

The thickness is progressively reduced in this manner until the lightest class of pipe is reached, and the maximum internal diameter is given. By doing this, one standard outside diameter is maintained for all classes of a given nominal inside diameter, and a standard outside diameter adopted for which the foundries already have fixtures on hand, and their objection of having to make new fixtures and multiplicity of patterns is met.

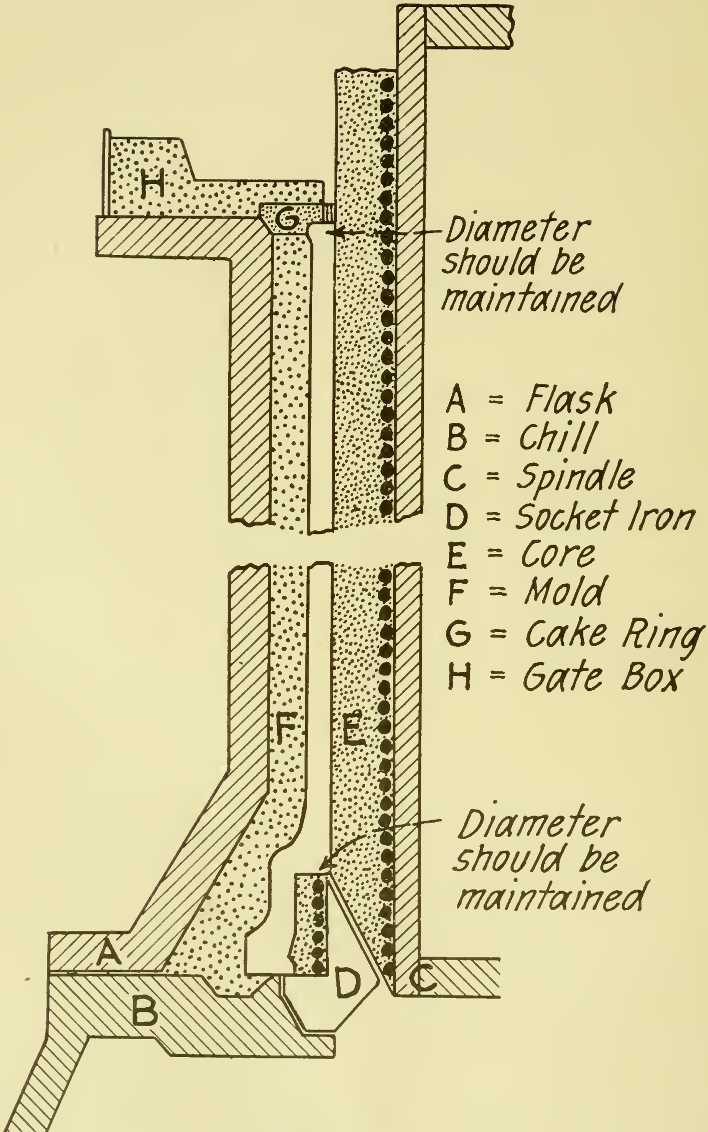

Diameter
should be
maintained
A = Flask
B = Chill
C = Spindle
D = Socket Iron
E = Core
F = Mold
G = Cake Ring
H = Gate Box
Diameter
should be
maintained
H
G
F
E
A
B
D
C

FIG. 1

But the foundries' contention of a multiplicity of various fixtures is not altogether met yet, for just as soon as there is a departure from a fixed diameter for that part of the core which forms the extreme end of the barrel of the pipe (the end next the socket and the end forming the spigot), it necessitates a change in fixtures, and is therefore undesirable. (See Fig. 1.)

Under present methods of pipe manufacture, — and our best pipe makers have discovered no other, — it would be impossible to make pipe of various internal diameters and with straight inside lines (see Fig. 2) without multiplying the fixtures quite rapidly, but these can be very materially reduced; in fact, the reduction would then involve only a variety of core bars, and in the case

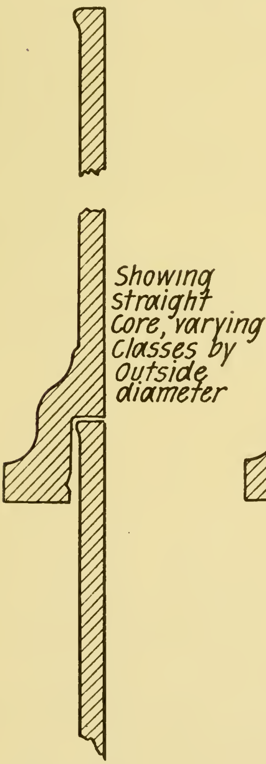


FIG. 2

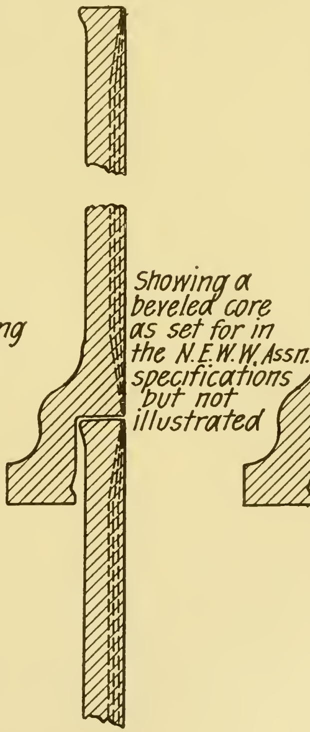


FIG. 3

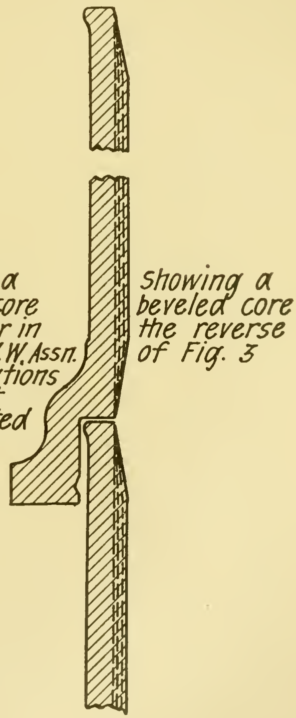


FIG. 4

of the larger diameters of pipe, possibly two sets of core bars or spindles would cover the variety of classes, thus:

By maintaining a set diameter at the ends of the core, and beveling the core for a distance from the ends, either toward the center from the lightest class to the heaviest, the heaviest class to be straight inside (see Fig. 3), or reverse this bevel so that the lightest pipe is straight inside, and as the weight increases the bevel increases (see Fig. 4). Your present specifications make provision for the beveling of the cores as shown in Fig. 3, but it is not illustrated in any way, and is, I believe, not altogether understood.

There has been, almost ever since Standard Pipe Specifications have been discussed by any of the associations that have to do with their use, the question of whether it is possible to obtain one outside diameter for all classes of pipe of a given size; and offhand, except on a few of the smaller sizes where the extremes of variation as between the heaviest and the lightest pipe is a matter of only a few hundredths of an inch, I should say, no, unless some method of beveling the cores is resorted to. The question resolves itself to this: to have a uniform outside diameter for all classes of a given size is desirable, as it will enable any purchaser to order from the foundry any size and number of classes with the assurance that he will receive pipe that will all go together, and will enable the manufacturer to make up for stock pipe that will always go together with other pipe from his own or other manufactories, — he classifying them by weight merely in his stock yard.

On the other hand, it is well understood that in the matter of friction, etc., it is desirable to have the interior surfaces of the pipe as nearly straight and smooth as it is possible to get, and that to have them beveled would be a deviation from this principle. The question is, Which idea has the greatest advantage? There is another matter that would have to be considered, too, and that is, that for entirely new plants, a uniform outside diameter works out all right, and would continue to do so; but would a 12-inch pipe of, say, $13\frac{3}{8}$-inch outside diameter work in on an extension or replacement in existing lines that might have been made up of light pipe on a base of 12 inches only plus the thickness of wall, say, $\frac{1}{2}$ an inch, making the outside diameter of only 13 inches and

possibly the bell opening $13\frac{3}{4}$ inches? I am inclined to believe that if there was a thorough determination to adapt themselves to it, the management of existing works could and would readily find that conditions would not be as bad in such an incident as at first glance it might seem.

Relative to that portion of specifications which would be text, rather than a table of dimensions, I would note the following: Up to the time the New England Specifications were drawn the usual custom of those purchasers accepting any pipe cut and banded had been to allow 6 per cent. of any given size ordered to be so cut and banded. In compliance with an urgent request from the manufacturers, this was increased to 12 per cent. for 12-inch pipe and larger, and none for sizes less than 12 inches. The result has been in many instances a percentage of bad spigots greatly in excess of 12 per cent., and it has seemed that this allowance should be reduced, so as to try and avoid at least the intimation from some quarters that a premium has been placed on careless workmanship. Another matter is the proneness of the foundry to turn pipe out of the flasks while too hot; and the specifications should be so worded that the manufacturer suffers the penalty of losing the pipe if this is done in any instance, for while it may not be apparent in the pipe at the time, there will result an inequality of the strain on the molecules of iron, which makes the pipe a dangerous one and liable to burst at any time, even after passing all of the tests.

Further, at most of the foundries the life of the inspector for the purchaser is rather a strenuous one, and one of the requirements that might well be inserted would be one requiring the manufacturer to turn out all the pipe being made for any particular purchaser so that they are not mixed with other pipe for other parties, and also to clean, coat, weigh, prove, and pile or ship one day's cast before putting any of a subsequent day's cast through. This would be a decided relief to an inspector, and would enable him to report his work promptly to his employers, and eventually the foundries would, I believe, find it work to their advantage.

DISCUSSION.

MR. T. H. MCKENZIE.* Mr. President, I should like to inquire the opinion of the gentleman as to whether first-class foundries do not turn out pretty nearly as good pipe without inspection as they do with inspection? That is, won't it stand the pressure just as well, stand all tests the same, whether it is made under contract or not, — a pressure, we will say, of 300 pounds to the square inch? I shouldn't think it would be for the interest of the manufacturer to turn out defective pipe, whether an inspector is employed or not.

MR. CONARD. Mr. President, I wouldn't be doing myself justice if I were to say that it wasn't an advantage to have your pipe inspected.

MR. MCKENZIE. I have bought them inspected and without inspection, and I never could see much difference.

MR. CONARD. Pipe is usually made with a hole in the end and round outside, and water goes through. If one is satisfied to accept them in that condition, all well and good.

MR. WALTER H. RICHARDS.† Mr. President, I recently had occasion to let a contract for cast-iron pipe. A combination of pipe manufacturers offered to furnish it to me, if they could furnish their own inspector and their own specifications. In other words, I could go without it or I could get it somewhere else, which I did.

The manufacturers are willing and anxious to write the specification, furnish the inspector, tell you how thick you want the pipe, and in fact do all the head work. It does seem to me that the party who purchases and pays for the pipe should have something to say about it, and this is best accomplished by having a specification and a good inspector at the foundry. The inspector should see the pipe before it is coated because it is impossible to detect a defect in casting after the coating is applied.

PRESIDENT WHITNEY. It seems to me that Mr. McKenzie's suggestion is almost too much of a temptation to the average pipe manufacturer. What do you think, Mr. Wood?

MR. WOOD. I don't quite catch your question.

PRESIDENT WHITNEY. Mr. McKenzie thinks inspection un-

* Civil Engineer, Southington, Conn.

† Engineer Water and Sewer Department, New London, Conn.

necessary. It seems to me that is putting almost too much temptation up to the pipe manufacturers.

Mr. Walter Wood.* I think the proper way to look at the matter of inspection is this: to a pipe manufacturer it is no disadvantage to have inspectors at his works. It is one of the easiest ways of keeping his men in order, because when you complain of your men not doing good work you can say the inspector said so, and you are relieved of any criticism from your labor. So I think any good pipe manufacturer should always be willing to have inspectors at his works, and I think, really, while we are talking on the subject, that this is the greatest use of pipe inspectors. I do not think that an inspector, as a rule, gets better pipe for a purchaser than if the buyer depended on the inspection of the pipe manufacturer which is based on long experience. Any pipe manufacturer aims to make good pipe, and I don't think he knowingly ships out any pipe which is bad. There is no doubt but a great many pipes are laid aside by inspectors which a pipe manufacturer would ship out. There is no question about it. I will tell you a story.

A prominent engineer said, "I have got a bully good inspector. It makes no difference whether pipe is 6 inches or 60 inches in diameter, if a fly lights on it and leaves a speck he finds it and rejects the pipe."

Mr. A. A. Reimer.† Perhaps it is too bad to take issue with the last speaker directly, but in East Orange we have had a rather sad experience without inspection, which may be something in the line of help to one of the previous speakers on this question. We have a good many miles of pipe, from 4 inches up to 24 inches, and for some years we demanded no inspection except on our large sizes of pipe. We got all of our pipe from one foundry, and felt, in consequence, that the foundry should at least keep East Orange in good shape when we wanted pipe, but it was our sad experience only two years ago to find that we were getting a poor quality of pipe. It was pipe, as Mr. Conard says, that was round on the end and outside, and it held water for a while, but that was about as near as it came to being real pipe. When I took up the

* Of R. D. Wood & Co., Philadelphia, Pa.

† Superintendent of Water Works, East Orange, N. J.

matter with the foundry and asked why we were treated in such a manner the president begged off, saying that he did not know that such pipe had been sent to us. I informed him that from that time we should employ an inspector. That is how Mr. Conard and I came to an understanding, and since then we have had pipe that is right.

Another point is this: in buying pipe without inspection I believe that all of us pay a big premium. I know we have. I believe that the manufacturer will send out pipe far heavier than we call for or need. Say, for instance, that you call for 6-inch pipe of a class that should weigh, perhaps, 385 pounds per length under the specifications. Your pipe will probably average, without inspection, fully 400 pounds per length, instead of 385, and in a large order that becomes a large item in paying for dead weight that does you no good, if the pipe you have called for will withstand the pressure you know to be sufficient.

I would like to relate an experience which came my way about a year ago. One of our neighboring cities called us up and wanted to get some pipe from us. We were in a position to help out and let them have all they needed. When they came to replace it we were asked if we wished to exchange on the basis of weight. The pipe in question was 6-inch, and we had sent them pipe weighing about 385 pounds per length, New England Water Works Association specifications. We were offered in exchange pipe weighing about 440 pounds per length, average. I wondered how this came about for I knew that no such weight of pipe was needed in that place. Then I recalled a conversation I had had some time before with the neighboring superintendent, in which he assured me that he had no trouble in getting pipe promptly and at a price nearly $4.00 per ton lower than we were paying. When the offer was made to return such heavy pipe, I understood why their price was so low. That place was paying for probably 100 pounds useless weight in each length, and then was getting pipe that had been rejected by others, the seconds and thirds of the foundry. So I believe in inspection.

And now, Mr. President, I wish to speak of one little matter at this time. Last fall at one of the meetings I had occasion to

mention by name a foundry that I criticised for failing to accept the New England Water Works Association specifications. At this time I wish to say, to be fair, that the United States Cast-Iron Pipe and Foundry Company, which is the one I criticised last fall for refusing to make pipe except on their own specifications, has very willingly complied with our specifications on the last few orders that we have placed. I think it is only due to them, inasmuch as I criticised them last year, that I should say that they are entirely fair and willing at the present time.

PRESIDENT WHITNEY. Is there anything further to be said in regard to Mr. Conard's paper?

MR. CONARD. Mr. President, it is a little unfortunate that all the discussion there has been on the paper has resolved itself down to the question of inspection. That wasn't at all the intention of the paper. It was intended to show you what could be done with cast-iron pipe *specifications*, and not what an inspector can do. It seems to me if we are going to have any discussion on the question of cast-iron pipe specifications it should be on the specifications themselves.

MR. MCKENZIE. Mr. President, I didn't want it understood that I wasn't in favor of inspection. I usually have an inspector myself, but I wanted to bring up a little discussion on the subject. As a rule you can inspect pipe on arrival and delivery, and with such inspection foundries are not liable to ship defective pipe.

PRESIDENT WHITNEY. I think you did bring out a little discussion, Mr. McKenzie. Perhaps it would be interesting to hear from a manufacturer on this subject, — as to changes in the pattern. Mr. Wood, what do you think of Mr. Conard's idea as to changes of patterns?

MR. WOOD. That question of the interior changing of the core or the outside diameter of the pipe was very thoroughly gone over between the committees of manufacturers and the New England engineers when the New England specifications were drawn up, and I think what is in the New England specifications on that point is as fair a conclusion as could be found. I don't think the manufacturers have any objection to the way it works out practically, although the engineers asked them to do something which

they felt would be somewhat of a burden. So I think the New England specifications on the inside and outside diameters is a fair agreement. I don't think either side has any wish to bring them up and criticise them.

There is one question which I do not quite understand the drift of in Mr. Conard's paper, — that is, the cutting off of the upper end of the pipe. There is no question but that it improves the casting — any casting — to have its upper end cut off. Any casting, even if it is apparently sound, has some slight defect which it is better to have cut off. I said so once before in one of the New England meetings, and I have been quite struck with some of the work we have been doing in this line. We have been trying cutting off the end of some of our pipe, and we have had people come back and say, "We prefer that kind of pipe; send us some more." It gives a cleaner, better end to the pipe, and specifications that provide for every pipe to be cut off will be a step in a better direction. It will give a higher grade of work altogether, give you better castings, and be more satisfactory in every way for yourselves and for the manufacturers, I think; the aim of all the manufacturers is to get good work, and cutting off the end of every pipe, 100 per cent., will give you very much better work than cutting the ends off from only 5 per cent. to 12 per cent.

Mr. Conard. Mr. President, I don't know as there is anything special to be said in reply to Mr. Wood's suggestion. The specifications now only call for an allowance of 12 per cent. of the pipe cast, and do not provide for any elongation being cast for cutting off. If the specifications were to be so arranged to apply to the cutting of 100 per cent. of the pipe, and called for an elongation to be cast on the end of the pipe, to take care of any bad metal there may be in the upper end, I agree with Mr. Wood that it can probably be accomplished, just so long as the workmen in the foundry will see to it that they maintain that good standard of workmanship. I don't for a moment want to be understood as criticising the manufacturers or the management of the pipe manufactories, because I think without exception they all want to furnish good work and all want to furnish the best workmanship possible, but there are often times when they can't keep track of all contingencies.

Mr. Wood. Perhaps I might say a word more. Of course, if every pipe is to be cut off there must be provision in the casting for cutting it off, and if the specifications are really brought up to the highest grade they will provide for five or six inches to be cut off of every casting; so you will always have a solid bead.

EXPERIMENTS ON VARIOUS TYPES OF FIRE HYDRANTS.*

BY CHARLES L. NEWCOMB, MECHANICAL ENGINEER, HOLYOKE, MASS.

[Presented by Robert E. Newcomb.]

(*Read November 13, 1907.*)

The fire hydrant, called in many places a fire plug, is an important part of the fire apparatus which our cities and towns are providing to guard against the fire hazard. The importance of this apparatus is at once seen when we remember that on the average each year over one hundred million dollars' worth of property is destroyed by fire in the United States.

The object of these tests was a complete investigation of the fire hydrants now commonly used, and the work was divided into the following classes:

1. The loss of pressure due to the friction of water in the hydrant, the total loss being subdivided into barrel loss and nozzle loss.
2. The discharging capacity of open hydrant butts at different pressures.
3. The water-hammer caused by quickly closing the main gate.
4. General features of construction, certainty of action, strength, durability, etc.

Some interesting data were also obtained on two 6-inch meters which were used in the tests.

A few tests on several different hydrants were made in 1886 by Prof. Selim H. Peabody, of the University of Illinois. The results of these were not entirely satisfactory. Mr. John R. Freeman, in his "Hydraulics of Fire Streams,"† gives a table the discharge of one open butt of a four-way independent gate hydrant at various pressures and some percentage corrections when using the table for other types of hydrants. Beyond

* Somewhat abridged from a paper presented to the American Society of Mechanical Engineers in 1899. (Trans. A. S. M. E., Vol. XX.) Published by permission.

† "Experiments Relating to Hydraulics of Fire Streams," Transactions, American Society of Civil Engineers, Vol. XXI, Table B – No. 3.

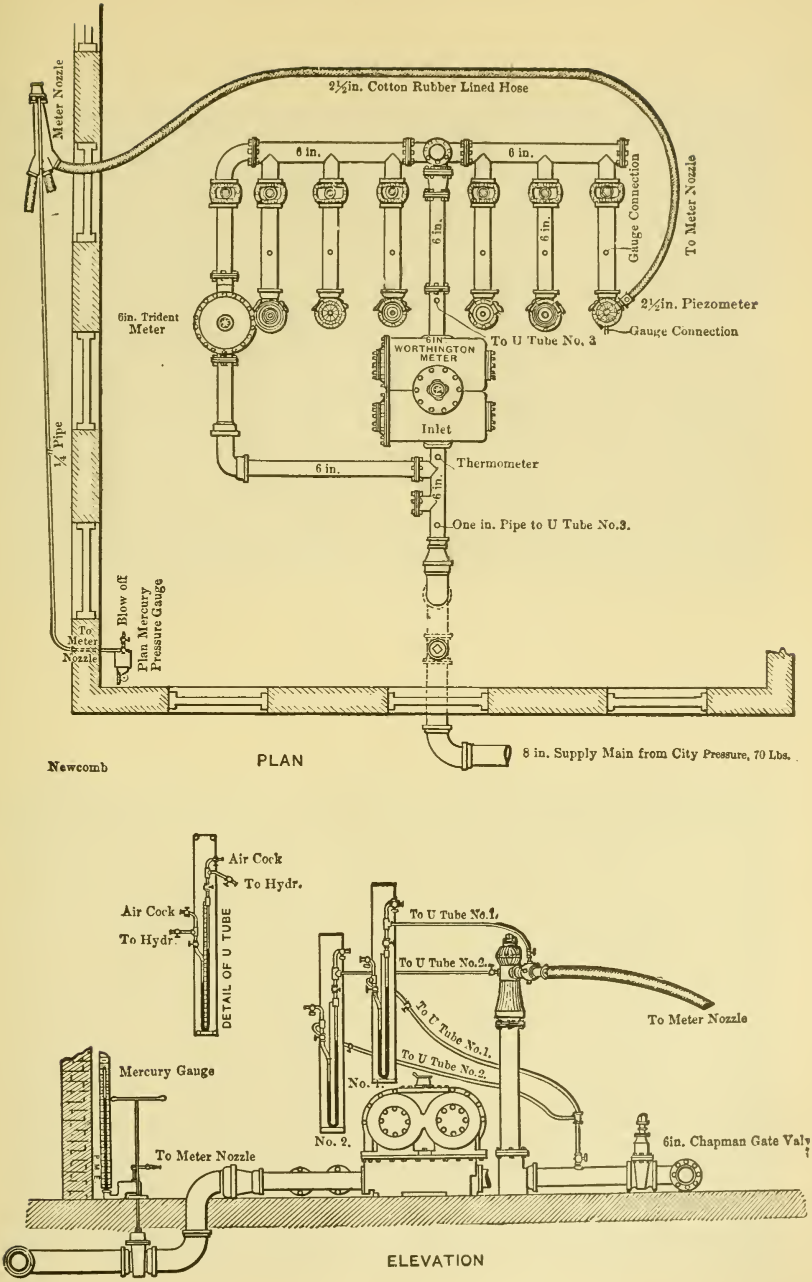


Fig. 1. Plan and Elevation of Piping, showing the Arrangement for Testing of Fire Hydrants, Holyoke, Mass., November, 1897.

these tests the writer has been unable to find anything of importance, though diligent inquiry was made. In the experiments here described it was possible to test a large number of hydrants under widely varying conditions, and the aim has been to bring out results which would be of value to hydraulic engineers and hydrant manufacturers.

The tests were made for the Water Department of the city of Holyoke, Mass., at the request of the water commissioners. They were carried on in the basement of the water-works shop, commencing in November, 1897, and ending in June, 1898, with an intermission of several months. The full facilities of the Water Department were at all times available, thus making it possible to go into the investigation with much thoroughness.

The writer is indebted to Mr. John R. Freeman, of the Factory Mutual Fire Insurance Companies, for valuable suggestions from his large experience in testing work, and for the general coöperation of the Inspection Department of Factory Mutuals. Mr. Frank L. Pierce and Mr. E. V. French, of this department, made frequent visits to the testing-room during the experiments and gave much help in planning the scope of the tests and the arrangement and handling of apparatus. The testing work done in 1897 and in January, 1898, was under the immediate charge of Mr. Ezra E. Clark, of Springfield, Mass. The work done in June, 1898, was under the immediate charge of Mr. A. L. Kendall, of the Factory Mutuals. Messrs. French, Clark, and Kendall have also aided in carrying on the computations and in getting the report in shape for publication.

The hydrants were in part bought from the manufacturers and in part loaned by them. In all cases it was fully explained that the hydrants were to be used in extensive tests and that the usual commercial article was desired. The cheerful cooperation of the manufacturers was of material help throughout the experiments.

The mercury gages and the meter nozzle were loaned by the inspection department of the Factory Mutuals. The Trident meter was loaned through the kindness of the Neptune Meter Company. The Worthington meter was purchased specially for the work.

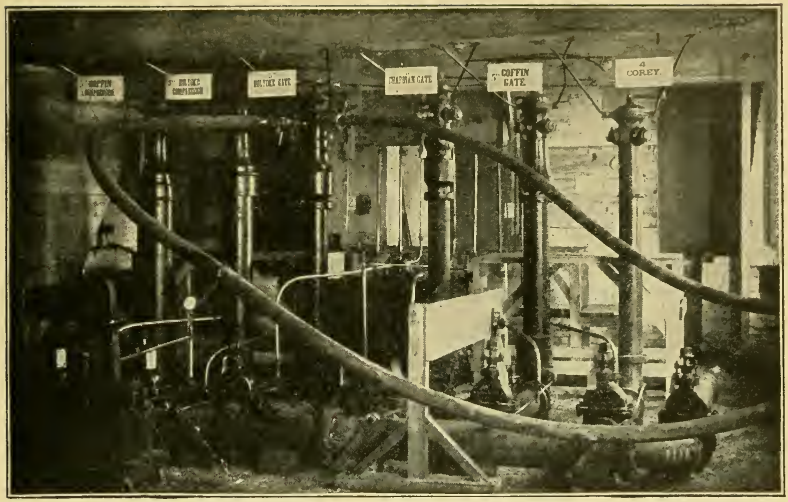


Fig 1. Interior of Testing-Room.

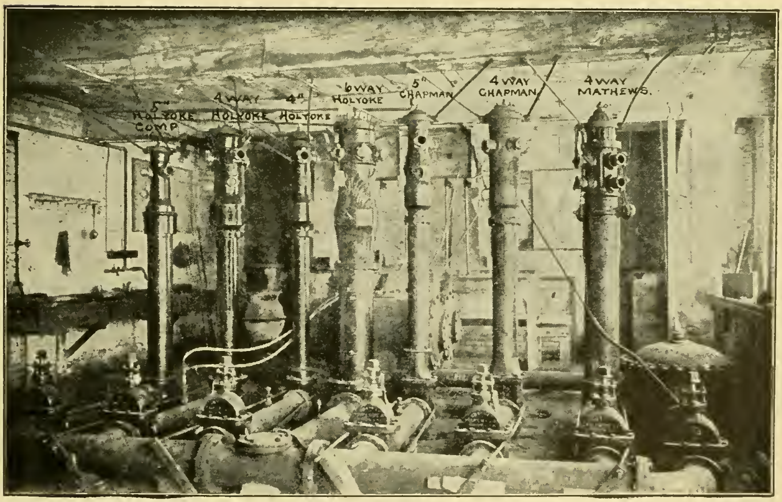


Fig. 2. Interior of Testing-Room.

the case at the outlet of a hydrant. At the end of the piezometer a 50-foot line of ordinary $2\frac{1}{2}$-inch cotton, rubber-lined, jacketed fire hose, loaned by the Fire Department, was attached, which conducted the water to a meter nozzle located in the yard. When two outlets were in use two lines of hose were employed, and for the three- or four-way hydrants three and four lines were used. With two lines of hose two piezometers were used and connected together by a short length of $\frac{1}{4}$-inch pipe. The connection for the U-gage was taken from about the middle of this pipe. When using more than two streams only two piezometers were used, it being assumed that the average pressure was fairly well secured in this way without the use of a piezometer on each outlet.

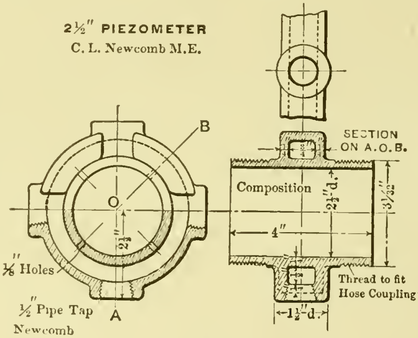


FIG. 2.

Meter Nozzle. The meter nozzle was one designed by Mr. John R. Freeman for accurate water measurement. A cut of it is shown in Fig. 3.* The three-way connection joins a $3\frac{3}{4}$-inch smooth-bore play pipe, having at its end a $3\frac{3}{4}$-inch piezometer made on the same principle as the $2\frac{1}{2}$-inch piezometer shown in Fig. 2. To the end of the piezometer nozzles from $\frac{1}{2}$-inch to $2\frac{1}{2}$-inch bore can be screwed. When using four streams an ordinary Siamese connection was screwed to one of the inlets. For the six streams in the tests of the six-way hydrant, the fifth and sixth lines were run separately and each provided with an Under-

* A full account of the original tests of this nozzle will be found in the Transactions, American Society of Civil Engineers, Vol. XXIV.

FIG. 1. EXTERIOR OF TESTING-ROOM, SHOWING METER NOZZLE IN OPERATION.

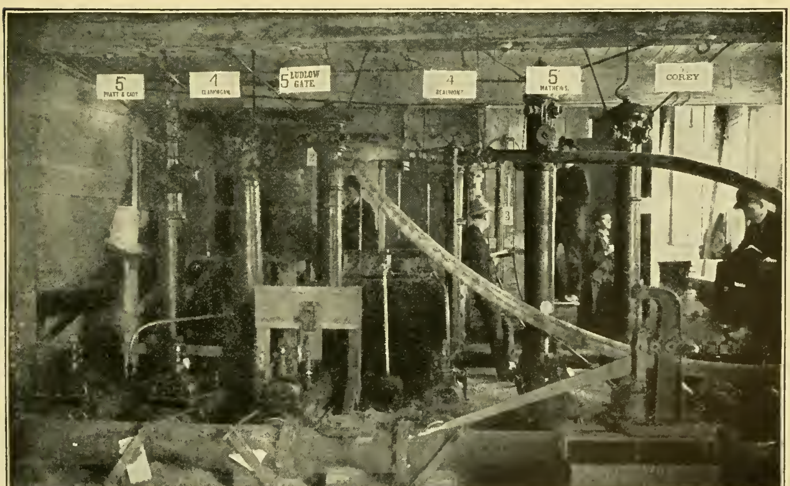
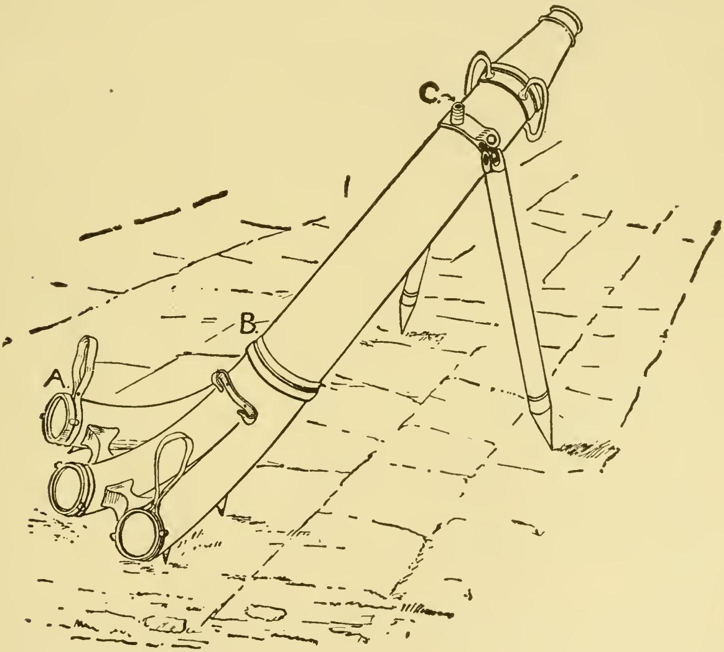


FIG. 2. INTERIOR OF TESTING-ROOM, SHOWING HYDRAULIC TEST PUMP ON RIGHT AND WATER-HAMMER RIG TO LEFT OF CENTER.

writer play pipe. At the base of one play pipe was a $2\frac{1}{2}$-inch piezometer, which was connected to the mercury column and turned on alternately with the meter nozzle.

With the pressure at the nozzle piezometer accurately known the quantity of water can be readily computed. In all the friction loss tests the quantities were determined by the nozzles rather than by the meter. The Worthington meter gave trouble from its pulsations affecting the gages, so that the by-pass connection shown at the left in Fig. 1 was put in and the meter abandoned.



C, Piezometer gage connection.

FIG. 3. METER NOZZLE.

Later the Neptune meter was put into this connection and used for the last part of the open-butt tests.

Gages. The nozzle pressures were measured by a mercury column * with a scale graduated to read pounds and tenths of a

* For the general construction of the mercury column, method of graduating the scale to compensate for lowering of the cistern, weight of mercury, etc., see "Hydraulics of Fire Streams," by J. R. Freeman, Transactions, American Society of Civil Engnieers, Vol. XXI.

pound directly, and to include a connection for the lowering of the surface of the mercury in the cistern. The gage was connected to the nozzle piezometer by ¼-inch iron pipe and rubber tubing, care being taken to have the joints practically tight. The pipe sloped upwards from the nozzle, and a blow-off cock was placed at the highest point so that all air in the connections could be surely blown out. The gage was set up against the rear brick wall of the building, and the tube extended into the second story of the shop through a hole in the floor.

Losses of pressure were measured between the 6-inch inlet and the connection at the top of the hydrant; also between the 6-inch inlet and the 2½-inch piezometer. Thus the first gave the barrel loss and the second the total loss. The difference was then the nozzle loss. These losses were measured directly on a U-tube mercury gage made and connected about as shown in Fig. 1. For this gage a heavy glass tube with an inside diameter of about ¼ inch was bent into the shape of a U with one leg about twice the length of the other. The tube was filled with mercury nearly to the top of the shorter leg. A short length of rubber tube was cemented to the top of each leg. This tube connected the glass to a fitting made up of ordinary ¼-inch pipe and containing stop-cocks and a blow-off cock for air. From these fittings connections of ¼-inch iron pipe or of rubber hose were taken to the points in the hydrants between which the loss was desired. Care was always taken to have the connections slope upward from the hydrant to the air-cocks so that when the cock was opened the swiftly flowing current of water washed out all air in the connections.

These gages gave directly the gross loss of pressure between the two points with which connection was made, this loss being the difference in height between the two columns less a slight correction for a column of water of a height equal to this difference. A measuring stick graduated directly in pounds and tenths of a pound was fitted between the legs of the tube and gave the readings directly in pounds.

Open-butt Tests. In the open-butt tests the water was discharged directly from the 2½-inch hydrant butt. The floor of the test-room was of brick laid in cement with a large drain all

prepared especially for this work, so that the water could be blown out anywhere in the room.

For the tests to and including No. 368 the mercury gage was connected to the 6-inch piezometer at the inlet of the hydrant, and a U-gage connected between this point and the connection on the back of the hydrant. The pressure at the outlets was then the mercury-column reading corrected for elevation less the friction loss through the hydrant, which was given by the U-gage. After test No. 368 the mercury column was connected directly to the nipple at the back of the hydrant barrel opposite the outlets. This gave the pressure directly at the outlets and was better than the first arrangement, as it avoided the errors of the U-gage.

Friction Losses. In all the tests observers were placed at the different gages and took readings simultaneously at the sound of a bell, a warning bell being struck five seconds before the time for the reading. The majority of the tests were of ten minutes' duration, and readings were taken each minute. A few of the tests were of five minutes' duration, and in these half-minute readings were taken.

The following program was adopted for all the friction-loss tests:

Condition.	Size of Meter Nozzle.	Approximate Pressure at Nozzle.	Approximate Gallons per Minute Flowing.
One hose outlet.............	$\frac{3}{4}$ inch	66 pounds	130
,, ,, ...	$1\frac{1}{8}$ inches	46 ,,	250
,, ,, ...	$1\frac{1}{4}$,,	33 ,,	350
,, ,, ...	$1\frac{3}{4}$,,	24 ,,	450
,, ,, ...	2 ,,	19 ,,	550
Two hose outlets............	$1\frac{1}{4}$,,	65 ,,	375
,, ,, ...	$1\frac{3}{4}$,,	30 ,,	500
,, ,, ...	$1\frac{3}{4}$,,	45 ,,	625
,, ,, ...	2 ,,	34 ,,	750
,, ,, ...	$2\frac{1}{2}$,,	17 ,,	850

In all cases after the water was started ample time was allowed before the readings were commenced, to make sure the water had come to a steady condition of flow.

Before or after each series of tests the zero reading of the mercury column was obtained by filling the gage connections with water and holding the end level with the center of the nozzle and then reading the gage.

At the end of a series of tests the averages were quickly computed and checked, and the gross loss in pounds and the gallons per minute discharged for each condition were plotted on cross-section paper and a curve drawn through the points. This gave a constant check on the work and quickly showed up any error. The occasional prompt finding of a discrepancy tended strongly to impress the observers with the need of care in taking readings and handling the apparatus. For this reason, and for the greater ease with which any trouble is located and remedied, and for the chance of studying the results and investigating at once while the apparatus is in place any special feature, this method of carrying the computations along with the work is believed of the greatest benefit to the experimenter. The chance of false readings was carefully guarded against by liberal blowing off of all connections before each test. For a number of hydrants series of tests were repeated to try the accuracy of the work, and it was almost invariably found that the two series agreed well within practical limits.

The question was raised whether the high velocity of water through the $2\frac{1}{2}$-inch hydrant butt might not cause such a contraction of the stream as to affect the readings of the U-tube. Two series of tests were therefore made on one hydrant, one with the $2\frac{1}{2}$-inch piezometer next to the hydrant outlet, which was the usual arrangement, and the other with a piece of $2\frac{1}{2}$-inch pipe about 2 feet long between the hydrant and the piezometer. A special test for the friction loss in this $2\frac{1}{2}$-inch pipe was then made, and, correcting for this loss, the results were found to be practically the same in the one case as the other, showing that the piezometer screwed directly to the hydrant could be relied upon for accurate results.

Computations. The average readings from each test have been copied on data sheets arranged with parallel columns. The main steps of the computations have also been put upon these sheets, thus giving a complete record of the work. The friction loss tests are arranged in alphabetical order according to the names of the hydrants, with all the tests on one make of hydrant grouped. The open-butt tests are in order of test numbers. For a few of the hydrants complete tests were not made for lack of time. The absence of data will show where these omissions occur.

The detailed tables of experimental results are not included with this paper since the Tables I to VI inclusive, and the diagrams, show " the results in brief." For further details reference may be made to Transactions, American Society of Mechanical Engineers, Vol. XX, where the tables are given in full.

Open-butt Tests. The general method of procedure was the same as for the friction tests. The mercury column and the U-gage, in the tests where it was used, were read in the same way and with the same care as in the friction-loss tests. The quantity of water was obtained from the meters, the Worthington meter being used in all of the earlier tests, the Neptune meter in the later ones. The exact time in which the meter registered an even number of cubic feet was noted with a stop match. To get an even number of cubic feet a definite number of revolutions of one of the dial hands was timed. This method is free from possible inaccuracies in the graduations of the meter registers.

The average readings from each test and the main steps of the computations have been placed on data sheets similar to those used in the friction-loss tests.

On several hydrants tests were run first with the pressure taken at the usual connection at the back of the barrel, and second with the pressures taken at a connection tapped into a cap screwed to the other outlet if a two-way hydrant, and to any one of the other outlets if the hydrant had more than two outlets. The plotted points from the two tests gave practically the same curve, showing that where more convenient there is no objection to using a tapped hydrant cap.

Curves. In addition to the rough plottings which, as already stated, were made as the work progressed, final curves were drawn from the completed results. It was from these curves, which give the best means of averaging the several experiments on any one hydrant, that the data for the tables designed for practical use were taken.

Figs. 22 to 43 inclusive show friction losses, giving actual friction losses for one coördinate and gallons per minute flowing for the other.

I

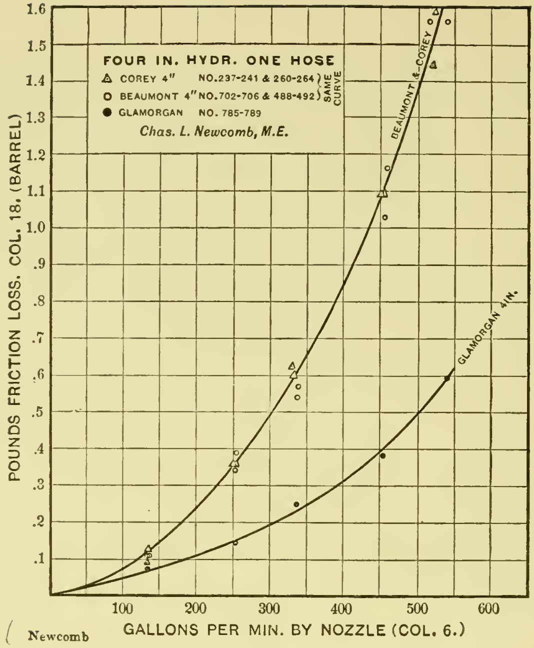


FIG. 22.

II

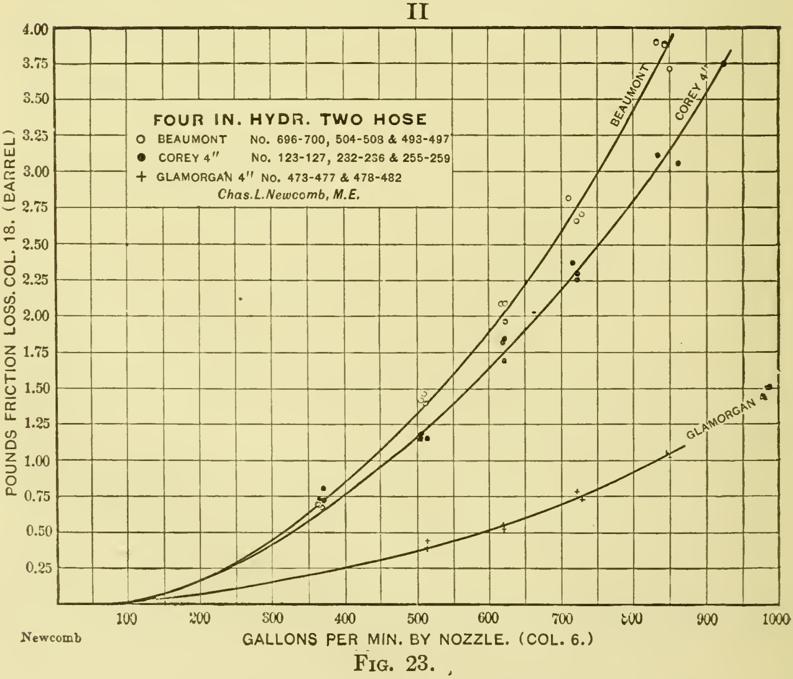


FIG. 23.

III

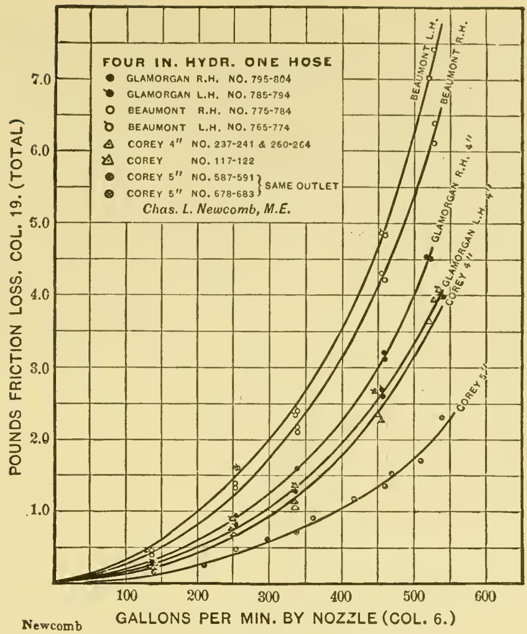


FIG. 24.

IV

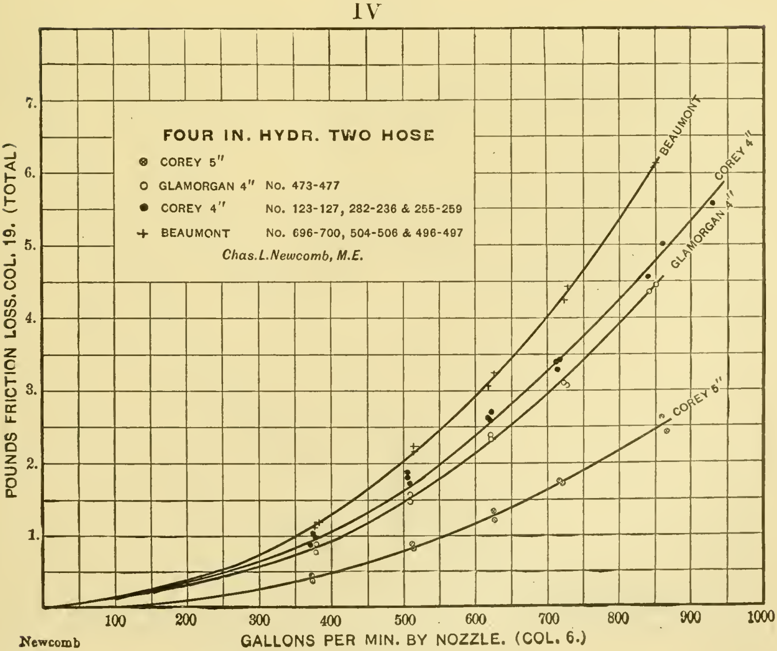


FIG 25.

V

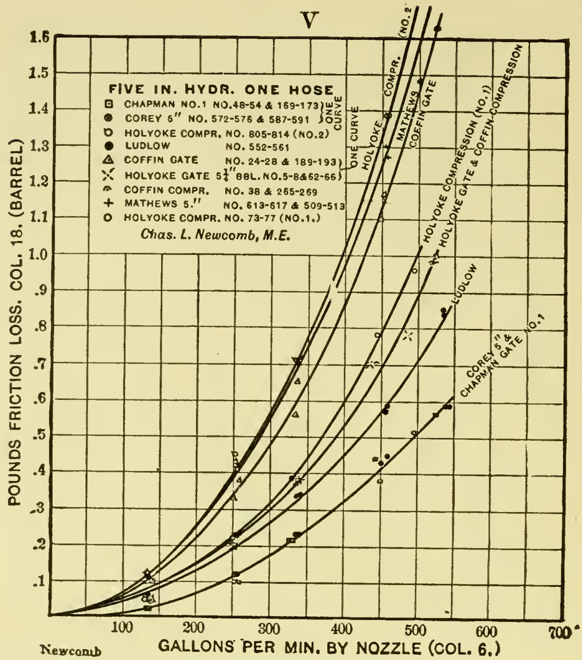


FIG. 26.

VI

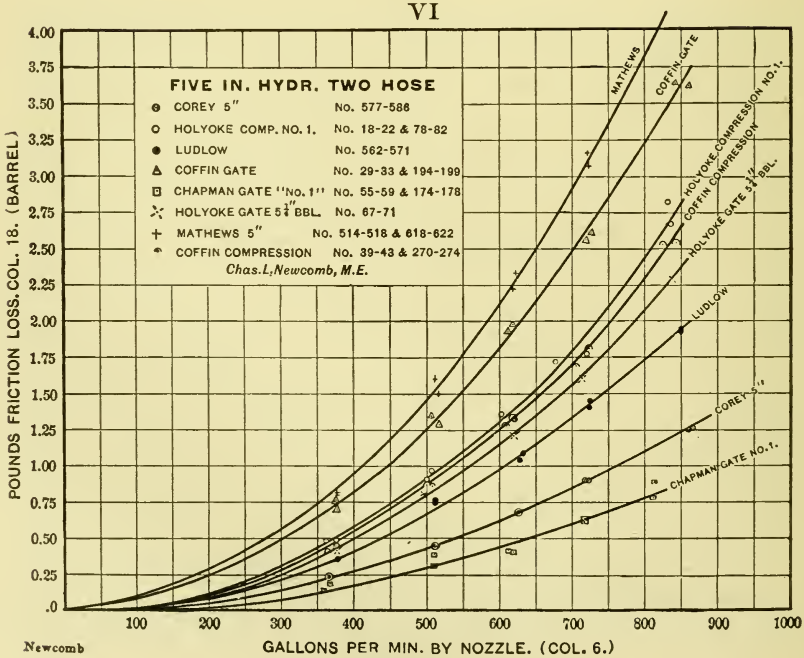


FIG. 27.

VII

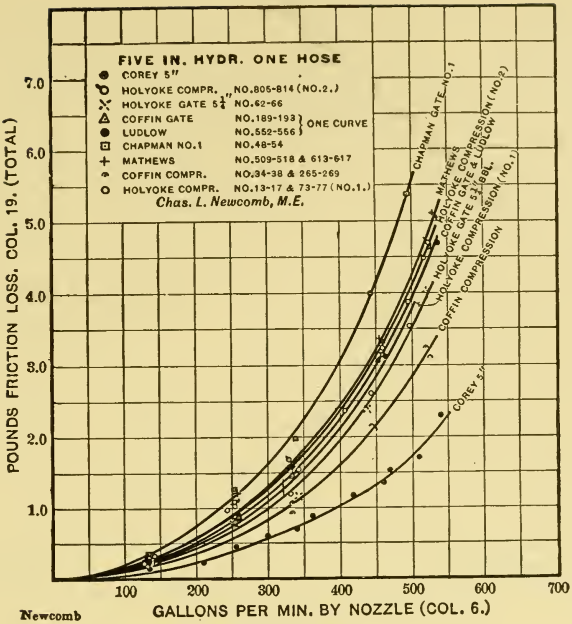


FIG. 28.

VIII

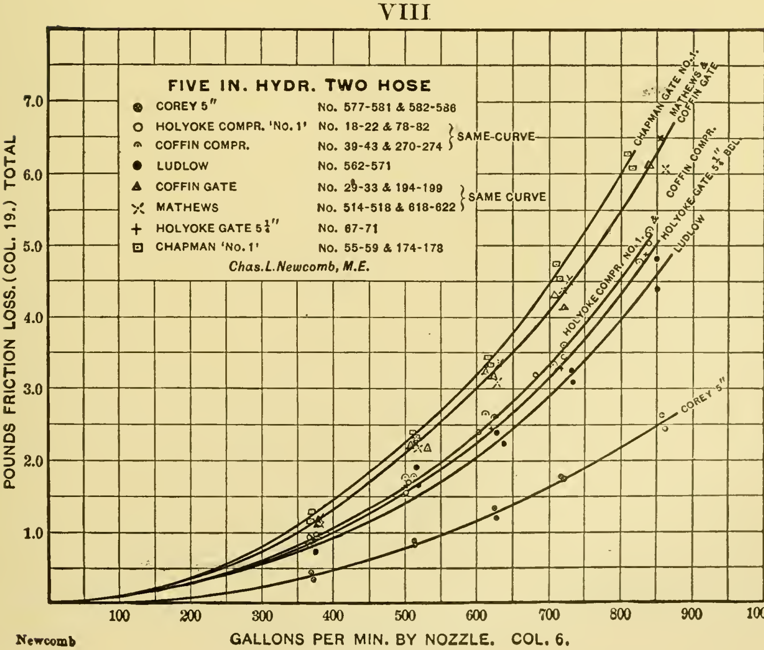


FIG. 29.

IX

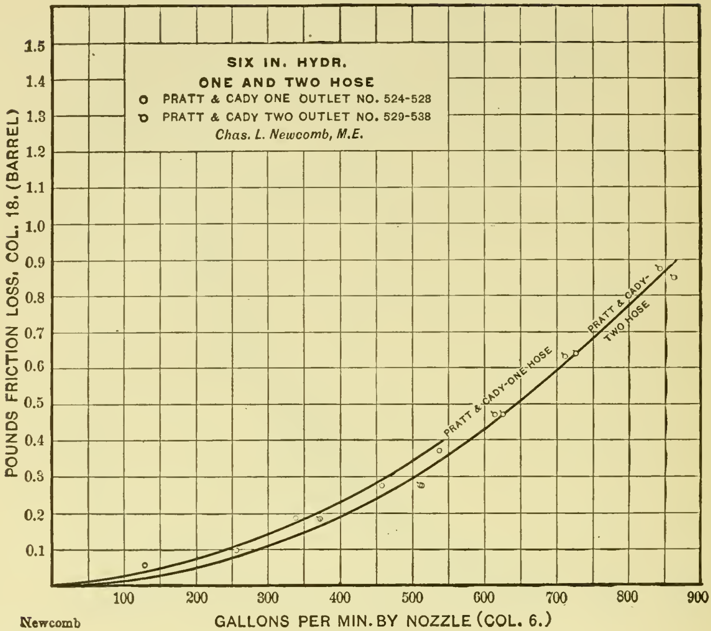


FIG. 30.

X

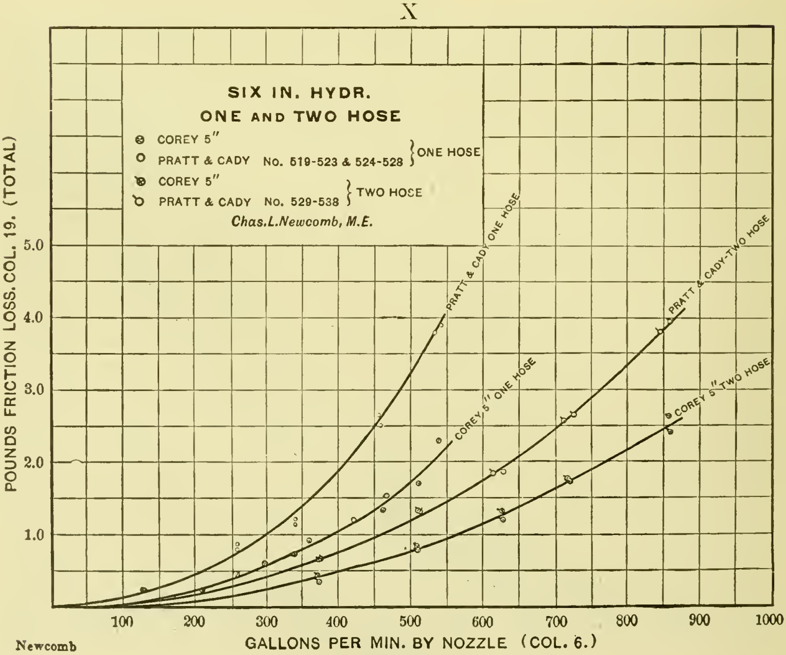


FIG. 31.

XI.

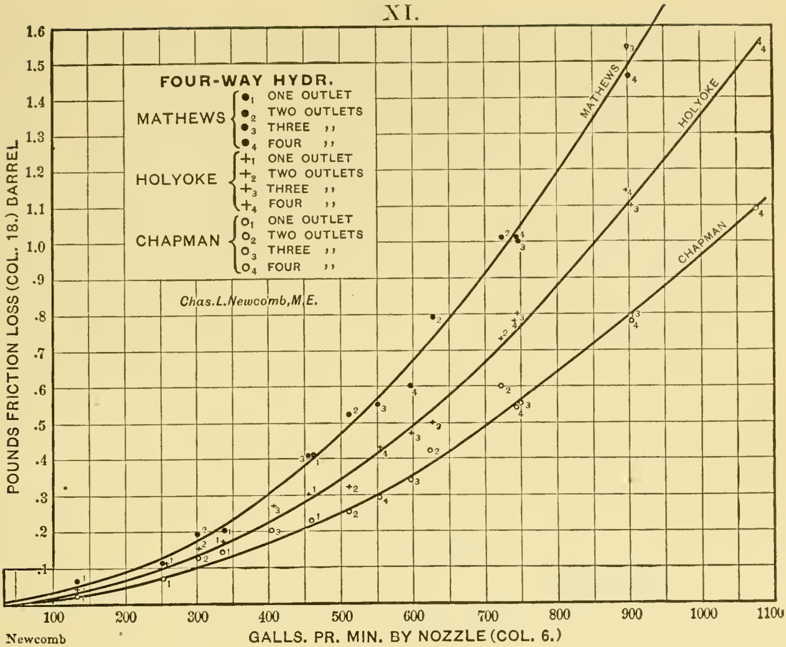


FIG. 32.

XII.

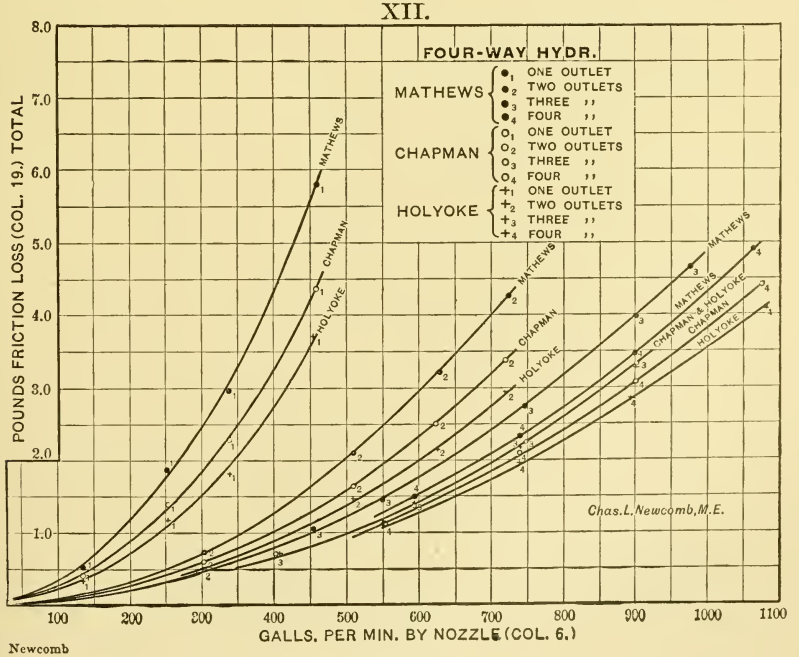


FIG. 33.

XIII

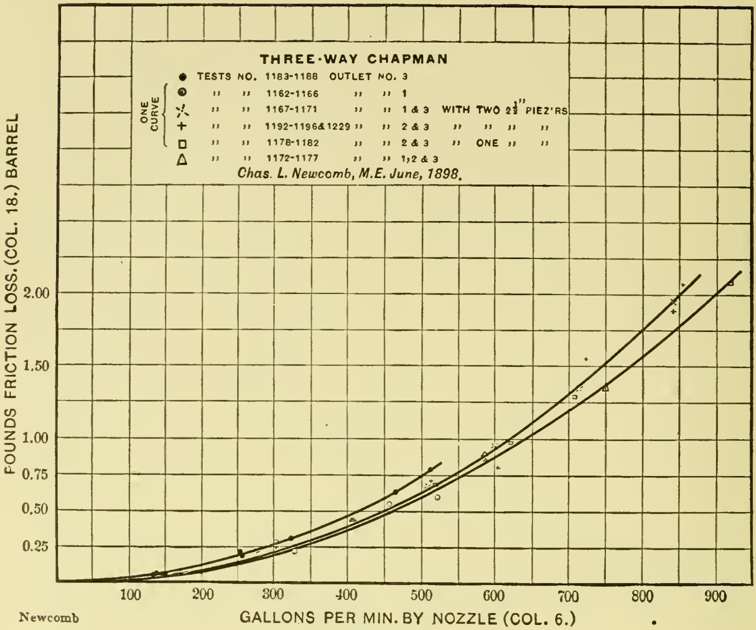


FIG. 34.

XIV

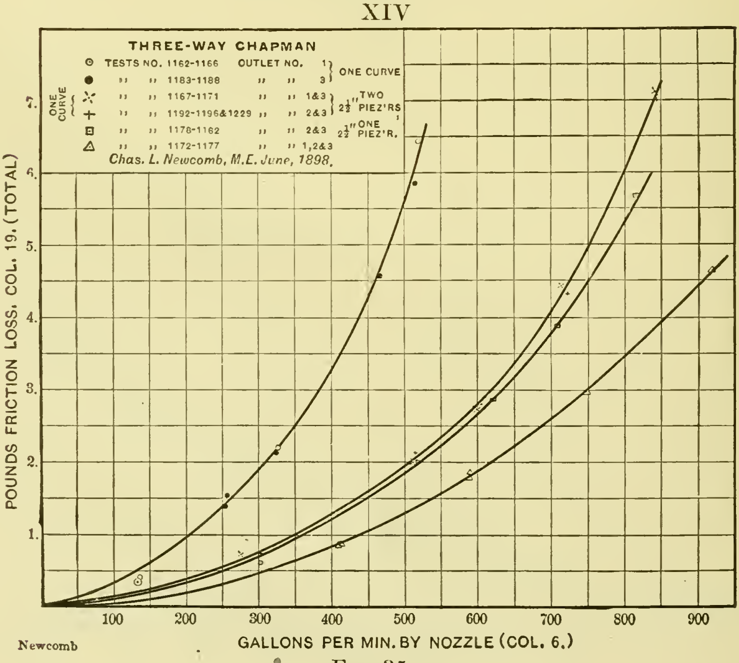


FIG. 35.

XV

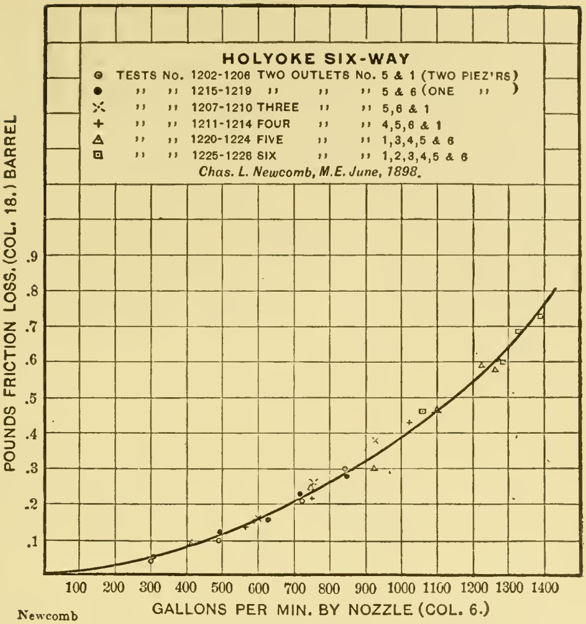


FIG. 36.

XVI

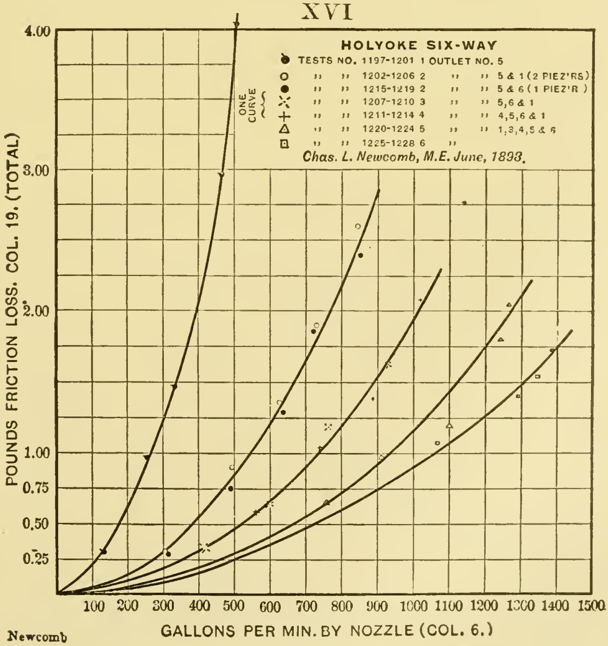


FIG. 37.

XVII

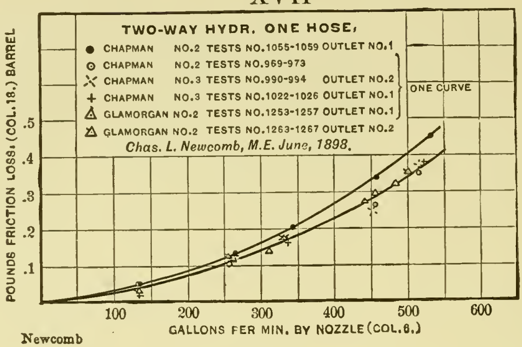


FIG. 38.

XVIII

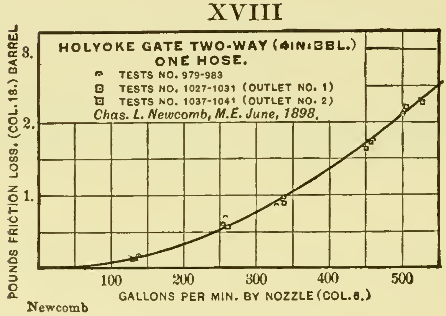


FIG. 39.

XIX

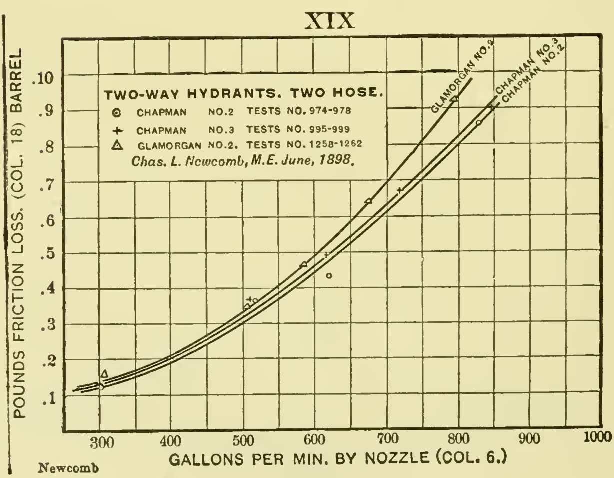


FIG. 40.

XX

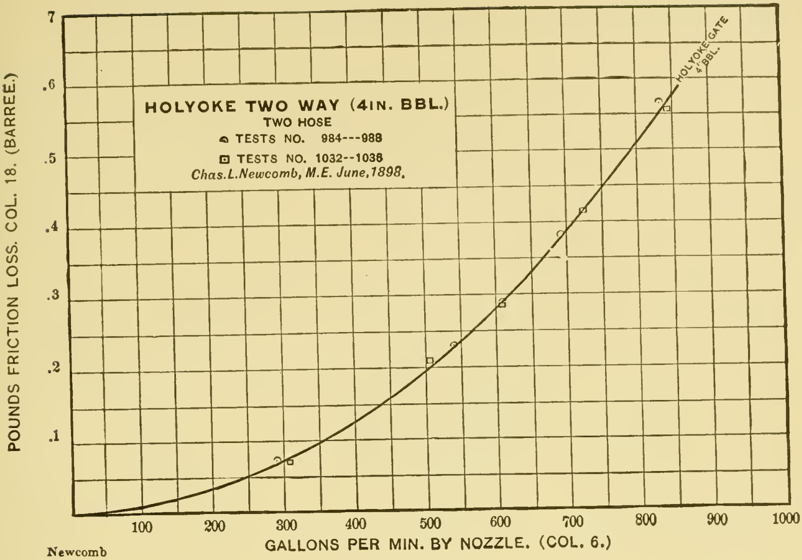


FIG. 41.

XXI

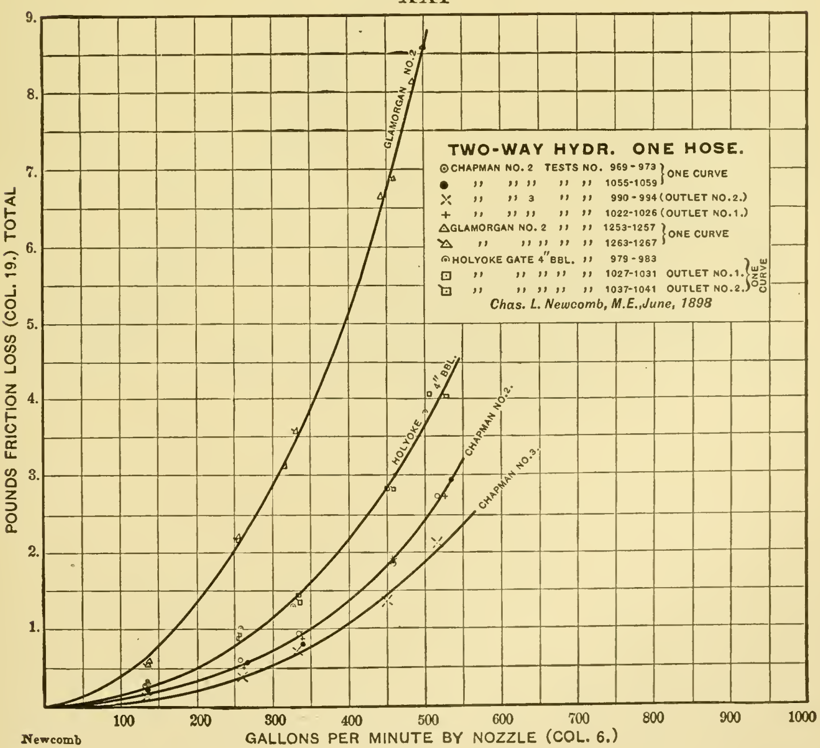


FIG. 42.

XXII

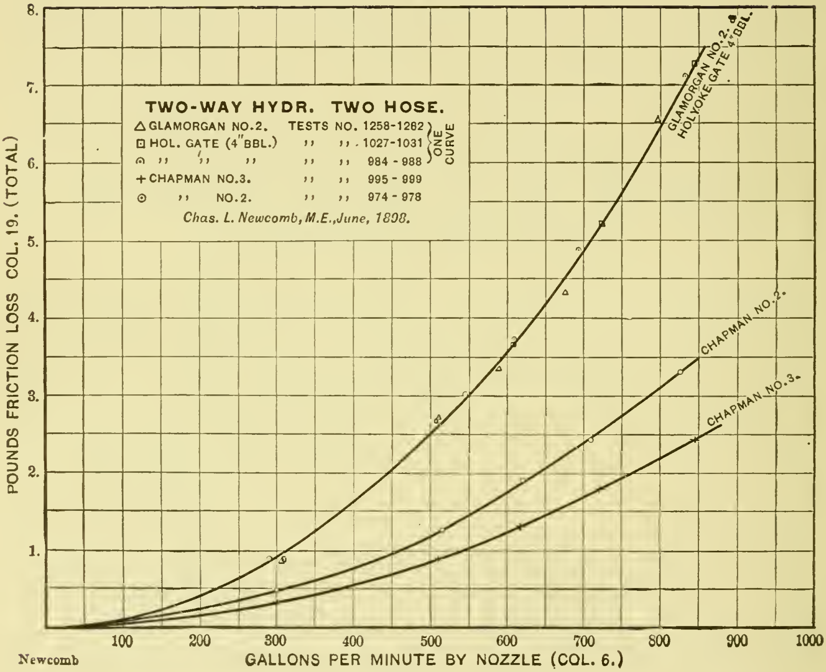
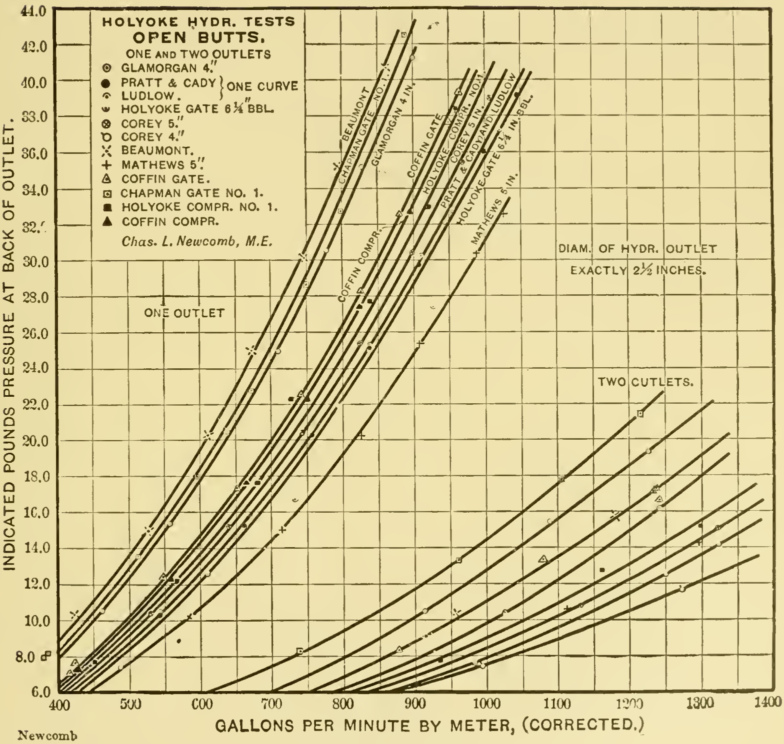

TWO-WAY HYDR. TWO HOSE.
△ GLAMORGAN NO.2. TESTS NO. 1258-1262
⊡ HOL. GATE (4" BBL.) " " 1027-1031
" " " " " 984 - 988
ONE CURVE
+ CHAPMAN NO.3. " " 995 - 999
⊙ " NO.2. " " 974 - 978
Chas. L. Newcomb, M.E., June, 1898.
GLAMORGAN NO.2.
HOLYOKE GATE 4" BBL.
CHAPMAN NO.2.
CHAPMAN NO.3.
POUNDS FRICTION LOSS COL. 19. (TOTAL)
GALLONS PER MINUTE BY NOZZLE (COL. 6.)
1. 2. 3. 4. 5. 6. 7. 8.
100 200 300 400 500 600 700 800 900 1000
Newcomb

FIG. 43.

XXIII



Newcomb

FIG. 44.

XXIV

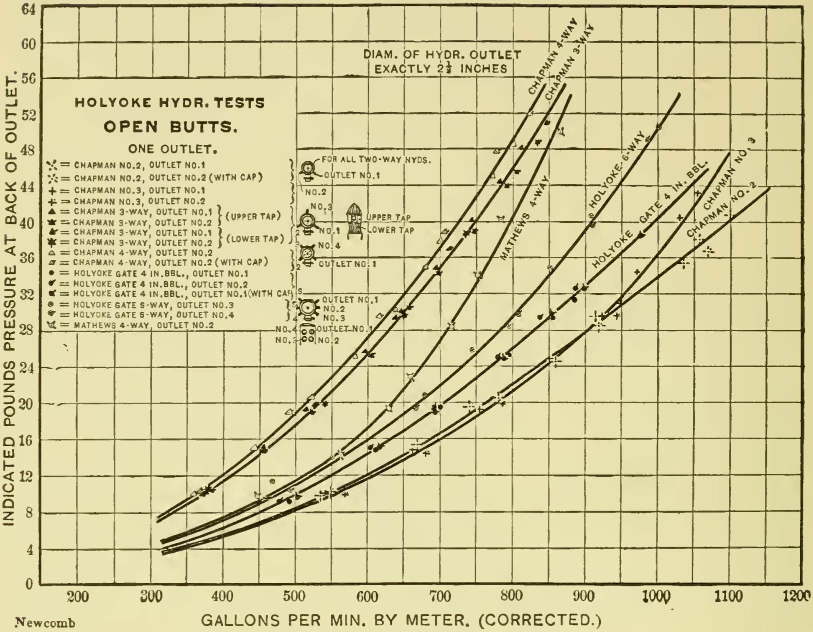


FIG. 45.

XXV

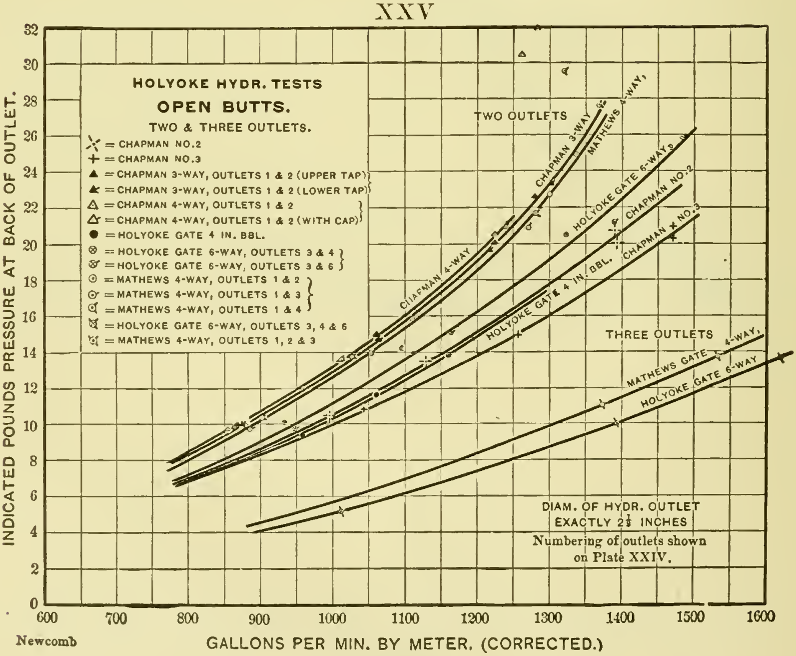


FIG. 46.

Figs. 44 to 46 give similar plottings for the open-butt tests, pressures at the back of the hydrant being taken for one coördinate, and gallons per minute for the other.

These curves give convenient means of studying the general uniformity of results and for interpolating between the points given in the summary tables. They also furnish a complete graphical record of the results which are shown in tabulated form on the data sheets. As many curves as were consistent with clearness have been plotted on one sheet, and in general hydrants of similar main dimensions will be found plotted together.

Accuracy. In the friction-loss tests the nozzle pressures were read to the nearest 0.1 pound, which represented a little less than one-quarter inch on the scale, and was, therefore, a very easily read division. The fluctuations under ordinary conditions, due to changes of pressure in the city mains, were less than one pound. When more than this, the unusual readings and the corresponding ones on the other gages were thrown out. It may safely be assumed that the nozzle pressures were correct within one-quarter of a pound. At the pressures worked at, this would mean an error in quantity of less than 1 per cent.

The U-gages in the later tests were read to the nearest 0.01 pound; in the earlier ones to the nearest 0.05 pound, except for the very small losses, where somewhat closer readings were made. At the small losses there was almost no vibration of the mercury columns, thus facilitating accurate readings. For the larger losses careful throttling of the cocks reduced the vibrations to a small range. By plotting these losses with the quantities corresponding, and locating an average curve through the points, the errors tend to neutralize each other, and it will be seen by studying the plates that the points do very readily locate such curves and that but few of them lie far outside the average line. Losses read from these curves may be considered correct within 2 per cent. Table I and the pyramid diagrams were made from the curves.

In the open-butt tests the mercury column was read to the nearest 0.1 pound. The average pressure from the ten readings would probably not be in error more than 0.2 pound and

in general not more than 0.1 pound. In the tests where the mercury column was connected to the 6-inch piezometer the U-gage error also enters, but in general this did not exceed about 0.1 pound. This means, when using the U-tube, a maximum error of 0.3 pound, and without the tube, 0.2 pound. The percentage errors decrease with the increase of pressures.

In estimating on the meter just when the dial hand with the meter in motion passes the zero point, an error of $1\frac{1}{2}$ cubic feet might be made. If the errors at the beginning and end happen to be the opposite direction, the maximum error would be 3 cubic feet. One hundred cubic feet was the smallest quantity passed in any test, and generally the quantity was considerably larger. Therefore in the worst case the percentage error in reading the meter does not exceed 3 per cent. The meters were calibrated by the nozzles, and an average curve plotted with meter readings for one coördinate, and nozzle quantities for the other. The errors in the meters were found to be practically constant for any given quantity, so that an error of over 1 per cent. in the calibration is improbable.

The stop-watch was read to the nearest one-fifth second and was frequently rated so that with ordinary care the time should be correct within 1 per cent., and often closer. With the above errors happening to be all in one direction the determination of the discharge per minute in any one test might be 5 per cent. out. This would be the worst condition, and in general the error would be much less.

In this work, as in the friction-loss tests, the results were plotted and average curves drawn. The results from these curves may reasonably be expected to be correct within 3 per cent.

Considering all the above, it will be seen that the results are amply accurate for all practical purposes.

HYDRANTS TESTED.

The following cuts, arranged in alphabetical order, show the general features and dimensions of the hydrants tested. A study of the results of the tests in connection with these cuts will show the reasons for the differences found.

Beaumont. Fig. 4 shows the general appearance of the hydrant tested. The casting towards the outlets was well rounded and the nozzles leaded in, making a smooth joint.

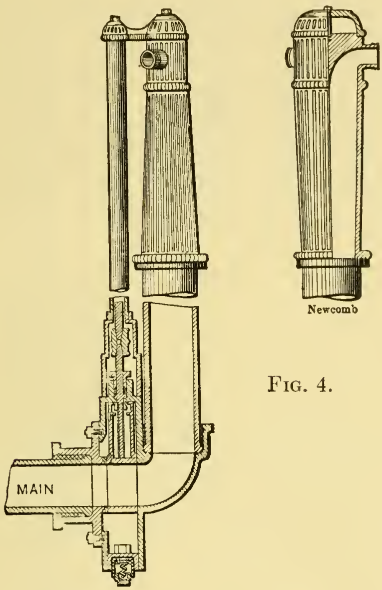


Fig. 4.

Inside diameter of cylindrical barrel, $4\frac{1}{8}$ inches.

Diameter of gate opening, $4\frac{1}{8}$ inches.

Fig. 5 shows a cross-section of hydrant barrel at gage connection.

Inside measurements at gauge connection 4⅞"x 2¾"

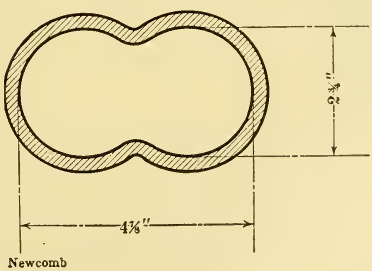


Fig. 5.

Chapman Nos. 1 and 2. Fig. 6 shows the general appearance of hydrants Nos. 1 and 2, but the hydrants tested were simple two-ways with no steamer connections. The dimensions given are for the hydrants tested. No. 1 was the regular commercial hydrant, and had sharp, jagged corners at the $2\frac{1}{2}$-inch outlets. In No. 2 the same casting was used, but the corners had been chipped and filed and made as smooth as possible, working from the outside. The result was fairly smooth curves, but of short radius, probably about $\frac{1}{4}$ inch.

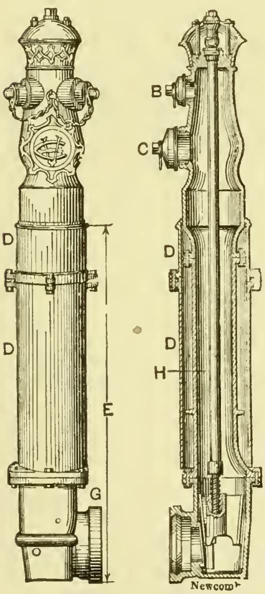


Fig. 6.

Gage connection: inside diameter of barrel at point opposite B

For No. 1, $4\frac{5}{8}$ inches.

For No. 2, 5 inches.

Smallest inside diameter of barrel, $5\frac{1}{4}$ inches.

Diameter of gate opening, 5 inches.

Chapman No. 3. Fig. 7 shows the new-pattern hydrant called No. 3. This was a two-way with steamer connection. The casting at 2½-inch outlets was smooth and well-rounded. Nozzles did not butt close against casting, but left a groove-like space about $\frac{1}{16}$ inch across.

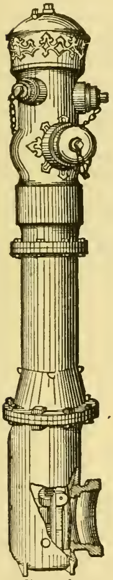


FIG. 7.

Inside diameter of barrel at gage connections, 7¾ inches.

Inside diameter of cylindrical barrel, 7 inches.

Gate opening, oval, 6⅜ inches by $5\frac{7}{16}$ inches; equal in area to circle 5. Nine inches diameter.

Chapman Three-Way. Fig. 8 shows the three-way independent gate hydrant. Nozzles projected into hydrant about $\frac{1}{4}$ inch and had flat ends, making sharp corners. The independent gate arrangement differs somewhat from that in the four-way hydrant. The guides are cast with the head and have rounded corners toward the current. The inside independent valve, when wide open, projects $\frac{1}{8}$ inch to $\frac{3}{16}$ inch into nozzle openings.

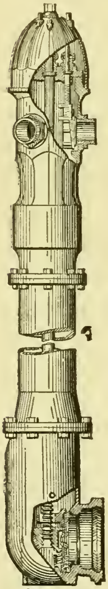


FIG. 8.

Barrel at gage connection, hexagonal; distance inside between flat faces, $6\frac{9}{16}$ inches.

Round inside diameter, 6 inches.

Cylindrical barrel inside diameter, $6\frac{3}{8}$ inches.

Gate opening, oval, $5\frac{7}{16}$ inches by $4\frac{5}{16}$ inches.

Chapman Four-Way. Fig. 9 shows the four-way independent gate hydrant. The lowest point on the independent gates projected about $\frac{1}{4}$ inch into openings when gates were wide open. This caused a noticeable breaking of the stream in the open butt tests.

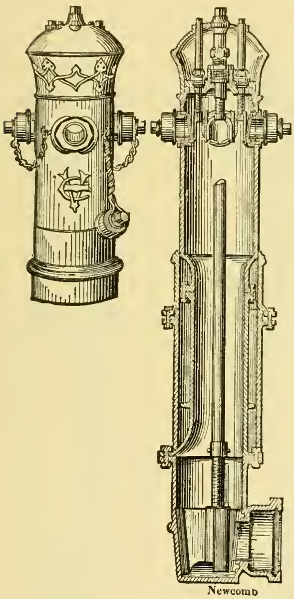


Fig. 9.

Gage connection: inside diameter of barrel, $8\frac{1}{4}$ inches.

Inside diameter of cylindrical barrel, $6\frac{3}{8}$ inches.

Diameter of gate opening, $6\frac{1}{16}$ inches.

Coffin Gate. Fig. 10 shows general appearance of Coffin hydrant, but the one tested had no steamer connection. Dimensions below are for hydrant tested. The nozzle entrances had well-rounded corners.

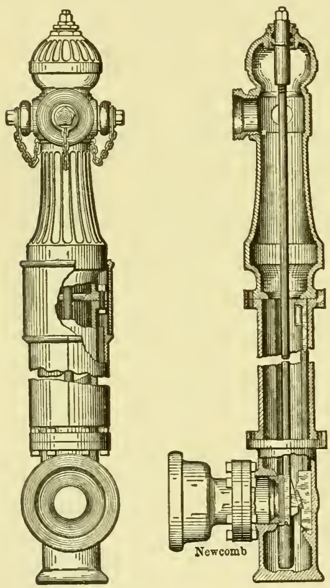


Fig. 10.

Inside diameter at gage connection, 6 inches.

Diameter at contraction, $5\frac{3}{8}$ inches.

Inside diameter of cylindrical barrel, $6\frac{1}{2}$ inches.

Diameter of gate opening, $4\frac{3}{4}$ inches.

Coffin Compression. Fig. 11 shows a two-way hydrant with steamer connection. The $2\frac{1}{2}$-inch nozzle entrances had well-rounded corners. This pattern has no contracted section like that in the gate hydrant.

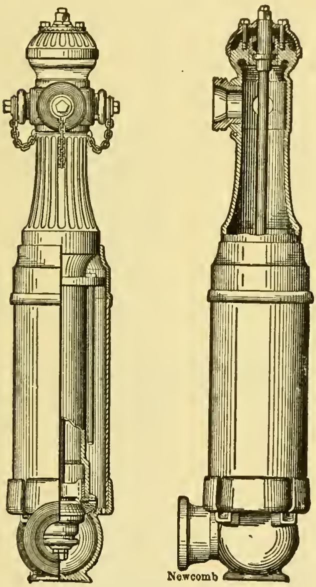


FIG. 11.

Inside diameter of gage connection, 6 inches.

Inside diameter of cylindrical barrel, 6 inches.

Diameter of gate opening, 5 inches.

Corey 4- and 5-Inch. Fig. 12 shows the general features of both 4-inch and 5-inch barrel hydrants. They were both two-ways and identical except for size. In this hydrant the barrel gage connection was enough below the outlet to enter the cylindrical part of the barrel.

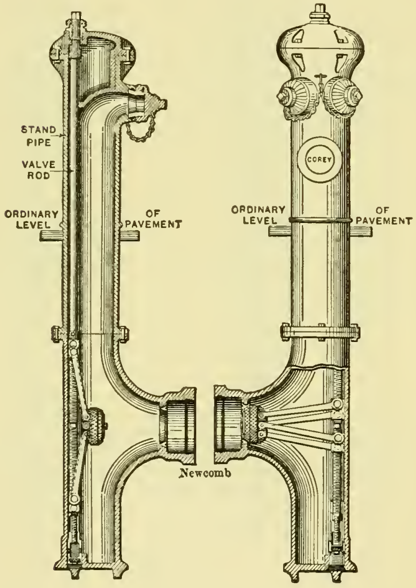


Fig. 12.

Inside diameters at gage connection:
For 4-inch barrel, $5\frac{3}{4}$ inches.
For 5-inch barrel, $6\frac{3}{4}$ inches.

Inside diameters of cylindrical barrel:
For 4-inch barrel, 4 inches.
For 5-inch barrel, 5 inches.

Diameters of gate opening:
For 4-inch barrel, 4 inches.
For 5-inch barrel, 5 inches.

Glamorgan. Fig. 13 shows the general features of the Glamorgan hydrants referred to as Nos. 1 and 2. The castings of both hydrants were similar except that the outlets of No. 1 were less than 180 degrees apart, or about like the ordinary hydrant. The nozzle outlets were not rounded, but presented square corners in the barrel.

No. 2 was fitted with independent cut-offs attached to outlets. These were of a peculiar design, working on the principle of a piston valve, the shutting off being accomplished by revolving an external collar which moved the valves over the ports. The ports compelled the water to make several turns over sharp corners, accounting for a large frictional loss.

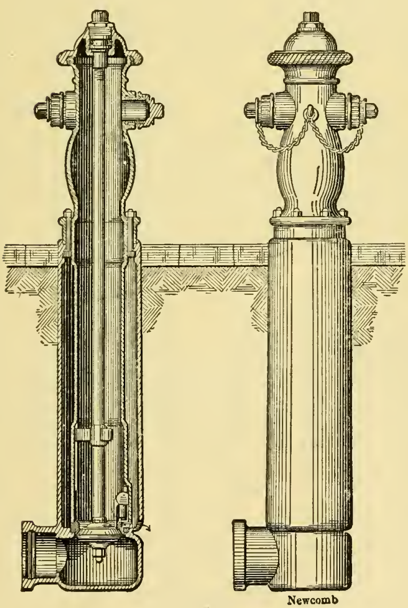


Fig. 13.

Inside diameters at gage connection:

For No. 1, $4\frac{3}{8}$ inches.

For No. 2, $6\frac{1}{2}$ inches.

Inside diameters of barrel at smallest part:

For No. 1, 5 inches.

For No. 2, $6\frac{3}{4}$ inches.

Diameters of gate opening:

For No. 1, $4\frac{1}{4}$ inches.

For No. 2, $6\frac{5}{8}$ inches.

Holyoke Gate (4-inch, $5\frac{1}{4}$-inch, and $6\frac{1}{4}$-inch barrel). Fig. 14 shows the general features of the nominal 4-inch, 5-inch, and 6-inch hydrants. These were all two-way. Casting at outlet had rounding corners, but was rough, with small nubbles and projections.

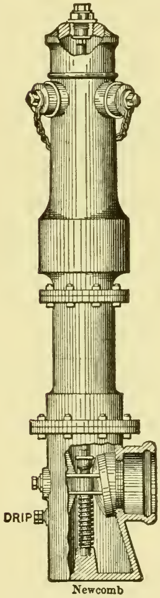


FIG. 14.

Inside diameters at gage connections:
For 4-inch hydrant, $5\frac{9}{16}$ inches.
For 5-inch hydrant, $6\frac{1}{8}$ inches.
For 6-inch hydrant, 7 inches.

Inside diameters of cylindrical barrel:
For 4-inch hydrant, $4\frac{3}{8}$ inches.
For 5-inch hydrant, $5\frac{3}{8}$ inches.
For 6-inch hydrant, $6\frac{3}{8}$ inches.

Diameters of gate opening:
For 4-inch hydrant, $4\frac{1}{16}$ inches.
For 5-inch hydrant, 5 inches.
For 6-inch hydrant, 6 inches.

Holyoke Compression Nos. 1 and 2. Fig. 15 shows the general features of hydrants Nos. 1 and 2, which were both two-way. The casting at outlet had rounding corners, but was rough, with small nubbles and projections.

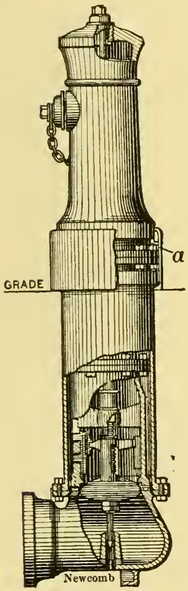


FIG. 15.

Inside diameters at gage connections:
For No. 1, $6\frac{1}{4}$ inches.
For No. 2, $5\frac{5}{8}$ inches.

Inside diameters of cylindrical barrel:
For No. 1, $5\frac{1}{4}$ inches.
For No. 2, 5 inches.

Diameters of gate opening;
For No. 1, $5\frac{1}{2}$ inches.
For No. 2, $4\frac{1}{2}$ inches.

Holyoke Four-Way. Fig. 16 shows an independent gate hydrant, the condition at the nozzles being as shown in the cut.

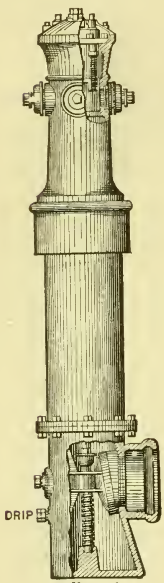


FIG. 16.

Inside diameter of barrel at gage connection, $7\frac{1}{2}$ inches.

Inside diameter of cylindrical barrel, $6\frac{3}{8}$ inches.

Diameter of gate opening, 6 inches.

Holyoke Six-Way. Fig. 17 shows the general appearance of the six-way independent gate hydrant tested. The main gate and barrel are of the same style as shown in Fig 14. The independent gates at the nozzle outlets are similar to those shown in Fig. 16.

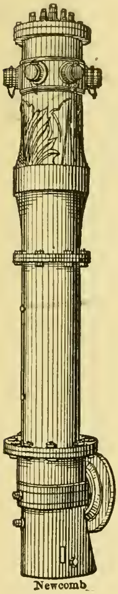


FIG. 17.

Inside diameters at gage connections:
For upper connection, $9\frac{1}{8}$ inches.
For lower connection, $9\frac{7}{8}$ inches.

Inside diameter of cylindrical barrel, 10 inches.

Diameter of gate opening, 8 inches.

Ludlow. Fig. 18 shows a simple two-way hydrant. The nozzle outlets were square-cornered, the sketch well showing the conditions.

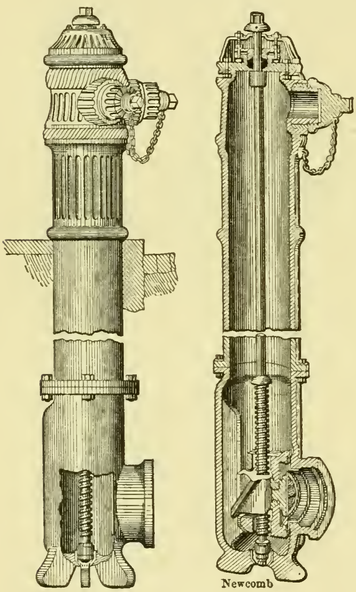


FIG. 18.

Inside diameter at gage connection, $7\frac{5}{8}$ inches.

Inside diameter of cylindrical barrel, 7 inches.

Diameter of gate opening, 5 inches.

Mathews 5-Inch. Fig. 19 shows the general appearance of the two-way compression hydrant, with steamer connection, tested. The hydrant was fitted with the double-valve arrangement, as shown in Fig. 19A. The casting of hydrant was rounded at the outlets to a radius of about $\frac{1}{4}$ inch, not having the square corners shown in the cut.

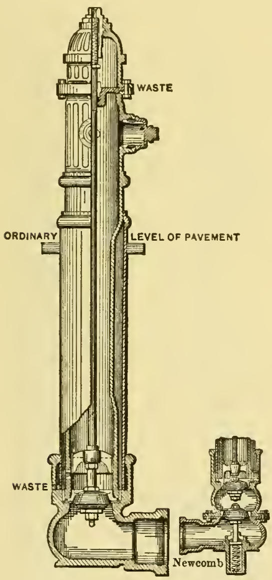


FIG. 19. FIG. 19A.

Inside diameter at gage connection, $7\frac{7}{16}$ inches.

Inside diameter of cylindrical barrel, 4 inches.

Diameter of both gate openings, $5\frac{5}{16}$ inches.

Mathews Four-Way. Fig. 20 shows the general appearance of a single-valve compression hydrant with independent gates at outlet. Fig. 19 shows the main valve arrangement of the hydrant tested, and Fig. 20 shows the design of the independent gates. In the hydrant tested the head was of somewhat different design to provide for the two additional outlets directly above those shown. When open the distance from valve face to outlet is from $1\frac{1}{2}$ inches to $1\frac{5}{8}$ inches.

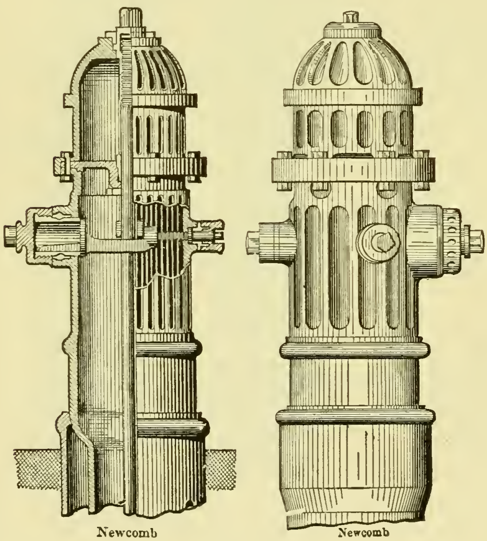


FIG. 20.

Inside diameter at gage connection, $8\frac{1}{2}$ inches.

Inside diameter of cylindrical barrel, $6\frac{1}{4}$ inches.

Diameter of gate opening, $6\frac{3}{8}$ inches.

Pratt & Cady. Fig. 21 shows the general appearance of the two-way hydrant tested, with steamer connection. The hydrant tested was fitted with independent gates for the $2\frac{1}{2}$-inch outlets. These gates were moved up and down by spindles through the head, somewhat similar to the Chapman and Holyoke hydrants, but the gates themselves had rounding surfaces following the curvatures of the barrel. The casting at the outlets had square and rather ragged corners.

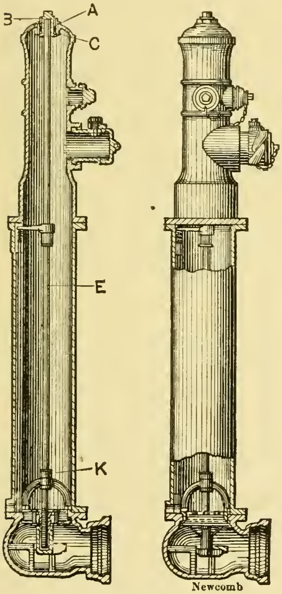


Fig. 21.

Inside diameter at gage connections, 6 inches.

Diameter of cylindrical barrel, $8\frac{3}{8}$ inches.

Diameter of gate inlet, $6\frac{1}{4}$ inches.

THE RESULTS IN BRIEF.

To put the results into shape for ready use the tables following have been prepared: Tables I, II, and III give the entire results of the friction-loss tests; Tables IV and V, the discharging capacity of open butts for the range of pressures covered by the tests. These tables were filled out by readings directly from the curves, Figs. 22 to 43 inclusive.

To further aid in making comparisons and to put all the friction-loss data into shape to appeal quickly to the eye, the pyramid diagrams, Figs. 47, 48, and 49, have been prepared. The points selected for these diagrams correspond to one or more standard fire streams; that is, 250 gallons per minute through each line of 2½-inch fire hose.

The open-butt tables are of value in testing water-works systems to determine their capacities at useful pressures where either lack of time or facilities prevents using more accurate apparatus. In such cases the open butt gives, quickly and inexpensively, fairly accurate results for this kind of work. Differences in design and construction of the outlet materially affect the discharge, but a study of the tables, together with the cuts of the hydrants, will enable one to apply intelligent corrections for outlets differing from any here tested.

In practice the gage would often be connected into a tapped hole in a hydrant cap and the cap screwed to one of the other outlets of the hydrant if it had more than one. This in all ordinary cases would give the same result as a connection tapped into the back of the hydrant, as was the case in most of the tests. The few tests in which the gage was connected first one way and then the other show practically no difference in the result.

TABLE I.

Hydrant Friction Losses—One Stream Flowing.

Name of Hydrant.	Friction Loss in Pounds with Various Rates of Flow. Gallons per Minute Flowing.														
	100			200			300			400			500		
	Barrel.	Nozzle.	Total.	Barrel.	Nozzle.	Total.	Barrel.	Nozzle.	Total.	Barrel.	Nozzle.	Total.	Barrel.	Nozzle.	Total.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
B'um't L. H. outlet	0.07	0.25	**0.32**	0.23	0.76	**0.99**	0.49	1.49	**1.98**	0.85	2.68	**3.53**	1.36	4.89	**6.25**
B'um't R. H. "	0.07	0.18	**0.25**	0.23	0.59	**0.82**	0.49	1.24	**1.73**	0.85	2.24	**3.09**	1.36	3.99	**5.35**
Chapman No. 1 ...	0.01	0.19	**0.20**	0.07	0.69	**0.76**	0.17	1.47	**1.64**	0.32	2.74	**3.06**	0.51	4.98	**5.49**
" No. 2	0.03	0.05	**0.08**	0.08	0.26	**0.34**	0.16	0.58	**0.74**	0.27	1.11	**1.38**	0.40	2.05	**2.45**
" No. 3	0.02	0.01	**0.03**	0.07	0.15	**0.22**	0.14	0.41	**0.55**	0.22	0.87	**1.09**	0.34	1.55	**1.89**
Chapman 3-way....	0.03	0.32	**0.35**	0.12	0.84	**0.96**	0.27	1.61	**1.88**	0.47	2.80	**3.27**	0.73	4.87	**5.60**
" 4-way....	0.01	0.24	**0.25**	0.04	0.82	**0.86**	0.10	1.72	**1.82**	0.17	3.03	**3.20**	0.25	....	.....
Coffin Gate.........	0.06	0.08	**0.14**	0.22	0.31	**0.53**	0.48	0.72	**1.20**	0.86	1.37	**2.23**	1.44	2.48	**3.92**
" Compression.	0.05	0.05	**0.10**	0.15	0.23	**0.38**	0.30	0.55	**0.85**	0.53	1.07	**1.60**	0.88	1.95	**2.83**
Corey 4-in..........	0.07	0.04	**0.24**	0.23	0.19	**0.42**	0.49	0.44	**0.93**	0.85	0.93	**1.78**	1.37	1.76	**3.13**
" 5-"	0.01	0.03	**0.04**	0.07	0.18	**0.25**	0.17	0.41	**0.58**	0.32	0.73	**1.05**	0.51	1.21	**1.72**
Glamorgan, No. 1..	0.05	0.10	**0.15**	0.11	0.39	**0.50**	0.19	0.87	**1.06**	0.31	1.63	**1.94**	0.49	2.83	**3.32**
" No. 2..	0.02	0.37	**0.39**	0.07	1.29	**1.36**	0.14	2.73	**2.87**	0.22	4.88	**5.10**	0.34	8.28	**8.62**
Holyoke Gate, 4-in.	0.10	0.03	**0.13**	0.35	0.14	**0.49**	0.77	0.38	**1.15**	1.36	0.81	**2.17**	2.10	1.57	**3.67**
Holyoke Gate, 5½-in.	0.05	0.07	**0.12**	0.15	0.29	**0.44**	0.30	0.70	**1.00**	0.53	1.41	**1.94**	0.88	2.61	**3.49**
" " 6½-"	0.03	0.07	**0.10**	0.12	0.28	**0.40**	0.26	0.60	**0.86**	0.49	1.10	**1.59**	0.82	1.79	**2.61**
" Comp. No. 1.	0.05	0.08	**0.13**	0.15	0.33	**0.48**	0.32	0.79	**1.11**	0.59	1.53	**2.12**	1.01	2.74	**3.75**
" " No. 2.	0.07	0.24	**0.31**	0.26	0.33	**0.59**	0.56	0.72	**1.28**	1.03	1.32	**2.35**	1.68	2.42	**4.10**
Hol'ke Gate, 4-way.	0.01	0.19	**0.20**	0.06	0.64	**0.70**	0.13	1.37	**1.50**	0.22	2.48	**2.70**	0.34	....	.....
" " 6-way.	....	....	**0.21**	....	....	**0.62**	....	....	**1.23**	....	....	**2.08**	....	....	**3.85**
Ludlow	0.04	0.10	**0.14**	0.13	0.40	**0.53**	0.26	0.94	**1.20**	0.45	1.78	**2.23**	0.71	3.21	**3.92**
Mathews 5 in.......	0.07	0.09	**0.16**	0.25	0.34	**0.59**	0.54	0.76	**1.30**	0.97	1.46	**2.43**	1.56	2.69	**4.25**
Mathews 4-way.....	0.03	0.29	**0.32**	0.09	1.09	**1.18**	0.18	2.22	**2.40**	0.31	3.99	**4.30**	0.47	....	.....
Pratt & Cady.......	0.02	0.12	**0.14**	0.07	0.39	**0.46**	0.14	0.87	**1.01**	0.23	1.68	**1.91**	0.34	2.92	**3.26**

TABLE II.

Hydrant Friction Losses—Two Streams Flowing.

Name of Hydrant.	Friction Loss in Pounds with Various Rates of Flow. Gallons per Minute Flowing.																	
	300			400			500			600			700			800		
	Barrel.	Nozzle.	Total.	Barrel.	Nozzle.	Total.	Barrel.	Nozzle.	Total.	Barrel.	Nozzle.	Total.	Barrel.	Nozzle.	Total.	Barrel.	Nozzle.	Total.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
B'um't L. H. outlet	....	....	.....	....	....	.....	....	....	.....	....	....	.....	....	....	.....	....	....	.....
B'um't R. H. "	0.45	0.28	**0.73**	0.82	0.48	**1.30**	1.32	0.70	**2.02**	1.87	1.04	**2.91**	2.57	1.44	**4.01**	3.41	1.94	**5.35**
Chapman No. 1 ...	0.08	0.74	**0.82**	0.17	1.32	**1.49**	0.30	1.97	**2.28**	0.44	2.79	**3.23**	0.61	3.86	**4.47**	0.78	5.24	**6.02**
" No. 2	0.12	0.36	**0.48**	0.19	0.58	**0.77**	0.30	0.88	**1.18**	0.44	0.30	**1.74**	0.61	1.79	**2.40**	0.80	2.30	**3.10**
" No. 3	0.13	0.19	**0.32**	0.20	0.33	**0.53**	0.31	0.51	**0.82**	0.46	0.75	**1.21**	0.63	1.04	**1.67**	0.82	1.36	**2.18**
Chapman 3-way....	0.20	0.55	**0.75**	0.38	0.91	**1.29**	0.62	1.33	**1.95**	0.92	1.86	**2.78**	1.30	2.75	**4.05**	1.75	4.24	**5.99**
" 4-way....	0.10	0.48	**0.58**	0.17	0.84	**1.01**	0.25	1.33	**1.58**	0.36	1.95	**2.31**	0.49	2.69	**3.18**	0.64	....	.....
Coffin Gate.........	0.50	0.25	**0.75**	0.82	0.54	**1.36**	1.26	0.86	**2.12**	1.82	1.20	**3.02**	2.48	1.61	**4.09**	3.23	2.25	**5.48**
" Compression.	0.28	0.35	**0.63**	0.55	0.53	**1.08**	0.87	0.78	**1.65**	1.26	1.14	**2.40**	1.71	1.63	**3.34**	2.30	2.29	**4.59**
Corey 4-in..........	0.42	0.23	**0.65**	0.75	0.32	**1.07**	1.16	0.47	**1.63**	1.62	0.73	**2.35**	2.18	1.06	**3.24**	2.78	1.49	**4.27**
" 5-"	0.14	0.12	**0.26**	0.27	0.22	**0.49**	0.43	0.35	**0.78**	0.62	0.54	**1.16**	0.86	0.78	**1.64**	1.11	1.08	**2.19**
Glamorgan, No. 1..	0.17	0.42	**0.59**	0.26	0.67	**0.93**	0.37	1.07	**1.44**	0.51	1.60	**2.11**	0.69	2.26	**2.95**	0.92	3.01	**3.93**
" No. 2..	0.14	0.78	**0.92**	0.21	1.41	**1.62**	0.33	2.17	**2.50**	0.48	3.07	**3.55**	0.69	4.15	**4.84**	0.93	5.54	**6.47**
Holyoke Gate, 4-in.	0.72	0.20	**0.92**	1.24	0.38	**1.62**	1.94	0.56	**2.50**	2.81	0.74	**3.55**	3.87	0.97	**4.84**	5.10	1.37	**6.47**
Holyoke Gate, 5½-in.	0.25	0.35	**0.60**	0.48	0.54	**1.02**	0.79	0.78	**1.57**	1.15	1.12	**2.27**	1.57	1.60	**3.17**	2.08	2.29	**4.37**
" " 6½-"	0.25	0.17	**0.42**	0.47	0.30	**0.77**	0.74	0.48	**1.22**	1.09	0.68	**1.77**	1.48	1.00	**2.48**	....	....	**3.36**
" Comp. No. 1.	0.31	0.32	**0.63**	0.58	0.50	**1.08**	0.92	0.73	**1.65**	1.30	1.10	**2.40**	1.80	1.54	**3.34**	2.44	2.15	**4.59**
" " No. 2.	....	....	.....	....	....	.....	....	....	.....	....	....	.....	....	....	.....	....	....	.....
Hol'ke Gate, 4-way.	0.13	0.35	**0.48**	0.22	0.65	**0.87**	0.34	1.03	**1.37**	0.49	1.51	**2.00**	0.67	2.08	**2.75**	0.88	...	.....
" " 6-way.	0.05	0.26	**0.31**	0.08	0.47	**0.55**	0.12	0.73	**0.85**	0.16	1.05	**1.21**	0.21	1.45	**1.66**	0.26	1.97	**2.23**
Ludlow	0.22	0.34	**0.56**	0.41	0.51	**0.92**	0.67	0.75	**1.42**	0.98	1.08	**2.06**	1.34	1.57	**2.91**	1.74	2.26	**4.00**
Mathews 5 in.......	0.57	0.18	**0.75**	0.95	0.41	**1.36**	1.47	0.65	**2.12**	2.12	0.90	**3.02**	2.92	1.17	**4.09**	3.83	1.65	**5.48**
Mathews 4-way.....	0.18	0.51	**0.69**	0.31	0.96	**1.27**	0.47	1.55	**2.02**	0.68	2.27	**2.95**	0.91	3.09	**4.00**	1.19	....	.....
Pratt & Cady.......	0.11	0.31	**0.42**	0.19	0.58	**0.77**	0.29	0.93	**1.22**	0.43	1.34	**1.77**	0.59	1.89	**2.48**	0.77	2.59	**3.36**

TABLE III.

Hydrant Friction Losses—Three to Six Streams Flowing.

Name of Hydrant and Gallons per Minute Flowing.	No. of Streams Flowing.	Friction Loss in Pounds with Various Rates of Flow.														
		Barrel.	Nozzle.	Total.	Barrel.	Nozzle.	Total.	Barrel.	Nozzle.	Total.	Barrel.	Nozzle.	Total.	Barrel.	Nozzle.	Total.
Gallons per Min.		500			600			700			800			900		
Chapman 3-way .	3	0.60	0.70	1.30	0.87	1.01	1.88	1.18	1.42	2.60	1.56	1.89	3.45	2.00	2.40	4.40
" 4-way .	3	0.25	0.70	0.95	0.36	1.05	1.41	0.49	1.46	1.95	0.64	1.96	2.60	0.80	2.51	3.31
Holyoke 4-way ..	3	0.35	0.60	0.95	0.49	0.92	1.41	0.67	1.28	1.95	0.88	1.72	2.60	1.11	2.20	3.31
" 6-way ..	3	0.12	0.35	0.47	0.16	0.50	0.66	0.21	0.69	0.90	0.26	0.92	1.18	0.32	1.21	1.53
Mathews 4-way ..	3	0.47	0.73	1.20	0.68	1.07	1.75	0.91	1.49	2.40	1.19	1.97	3.16	1.49	2.51	4.00
Gallons per Min.		600			700			800			900			1,000		
Chapman 4-way .	4	0.36	0.97	1.33	0.49	1.34	1.83	0.64	1.76	2.40	0.80	2.25	3.05	0.96	2.84	3.80
Holyoke 4-way ..	4	0.49	0.76	1.25	0.67	1.04	1.71	0.88	1.38	2.26	1.11	1.75	2.86	1.35	2.20	3.55
" 6-way ..	4	0.16	0.50	0.66	0.21	0.69	0.90	0.26	0.92	1.18	0.32	1.21	1.53	0.38	1.57	1.95
Mathews 4-way ..	4	0.68	0.84	1.52	0.91	1.16	2.07	1.19	1.53	2.72	1.49	2.04	3.45	1.81	....	4.32
Gallons per Min.		1,100			1,200			1,300			1,400			1,500		
Holyoke 6-way. .	5	0.46	0.98	1.44	0.54	1.21	1.75	0.63	1.47	2.10	0.75	....	....	0.91	....	....
" 6-way...	6	0.46	0.61	1.07	0.54	0.71	1.25	0.63	0.85	1.48	0.75	1.00	1.75	0.91	1.14	2.05

TABLE IV.

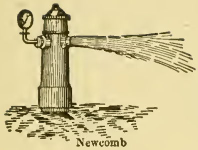


FIG. 209.

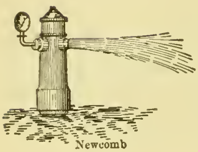
DISCHARGE OF ONE OPEN HYDRANT BUTT.

These figures apply only approximately to hydrants in general, because slight variations in construction, even in hydrants from the same shop, considerably affect the discharge from the open butt. The cuts of hydrants will suggest corrections, so that with good judgment results accurate within from 10 to 20 per cent. may, in general, be obtained.

NAME OF HYDRANT.	DISCHARGE THROUGH ONE OPEN BUTT OF HYDRANT WITHOUT HOSE ATTACHED. (DIAMETER OF OUTLET EXACTLY 2½ INCHES.) GALLONS PER MINUTE. Hydrant Pressure indicated while Stream is Flowing, by Gauge attached to Hydrant as shown.* Pounds per Square Inch.								
	10	15	20	25	30	35	40	45	50
Beaumont	426	526	608	678	743	799	852	......	....
Chapman No. 1	440	541	627	700	762	818	872	......	....
" " 2	547	667	765	853	938	1,020	1,098	......	....
" " 3	552	678	776	861	928	986	1,034	1,077	....
Chapman 3-way	371	458	531	593	648	701	748	792	834
" 4-way	363	444	513	573	630	680	725	767	806
Coffin Gate	497	607	701	780	850	913	974	......	....
" Compression	501	612	709	790	860	924	985	......	....
Corey 5-in	520	640	737	820	893	962	1,025	......	....
Glamorgan 4-in	449	550	636	709	773	831	886	......	....
Holyoke Gate, 4-in. bbl .	500	612	703	783	857	927	994	1,058	....
" " 6¼-in. bbl.	545	663	760	844	921	992	1,048	......	....
Holyoke Compr'n No. 1..	512	628	723	804	876	942	1,003	......	....
" Gate, 6-way....	473	579	668	743	805	860	908	954	997
Ludlow	533	653	752	836	912	982	1,049	......	....
Mathews 5-in	576	712	815	903	984	.....	......	......	....
Mathews 4-way...... ...	465	565	633	683	724	762	796	827	857
Pratt & Cady	533	653	752	836	912	982	1,049	......	....

* Pressure can be equally well measured by tap at back of barrel opposite outlets.

TABLE V.



Discharge of Two and Three Open Hydrant Butts.

These figures apply only approximately to hydrants in general, because slight variations in construction, even in hydrants from the same shop, considerably affect the discharge from the open butt. The cuts of hydrants will suggest corrections, so that with good judgment results accurate within from 10 to 20 per cent. may, in general, be obtained.

Name of Hydrant.	No. of Outlets Open.	Discharge through Open Butts of Hydrant without Hose Attached. (Diameter of Outlet Exactly $2\frac{1}{2}$ Inches.) Gallons per Minute. Hydrant Pressure indicated while Stream is Flowing, by Gauge attached to Hydrant Barrel as shown.* Pounds per Square Inch.				
		5	10	15	20	25
Beaumont	2	....	904	1,158	1,327	....
Chapman No. 1	2	....	827	1,020	1,173	....
" " 2	2	....	974	1,197	1,377	....
" " 3	2	....	997	1,252	1,448	....
Chapman 3-way	2	....	876	1,074	1,223	1,329
" 4 way	2	....	868	1,063	1,212	....
Coffin Gate	2	....	904	1,158	1,327	....
Corey 4-in	2	....	1,170	....	....	....
Corey 5-in	2	....	1,091	1,322	....	....
Glamorgan 4-in	2	....	894	1,082	1,248	....
Holyoke Gate, 4-in. bbl	2	....	985	1,202	....	....
" " $6\frac{1}{4}$-in. bbl	2	....	1,125	1,368	....	....
Holyoke Compression No. 1	2	....	1,051	1,278	....	....
" Gate, 6-way	2	....	942	1,152	1,326	1,466
Ludlow	2	....	1,008	1,200	1,364	....
Mathews 5-in	2	....	1,091	1,322	....	....
Mathews 4-way	2	....	890	1,089	1,238	1,341
Holyoke Gate, 6-way	3	992	1,388	....	....	....
Mathews 4-way	3	940	1,304	1,596	....	....

* Pressure can be equally well measured by tap at back of barrel opposite outlets.

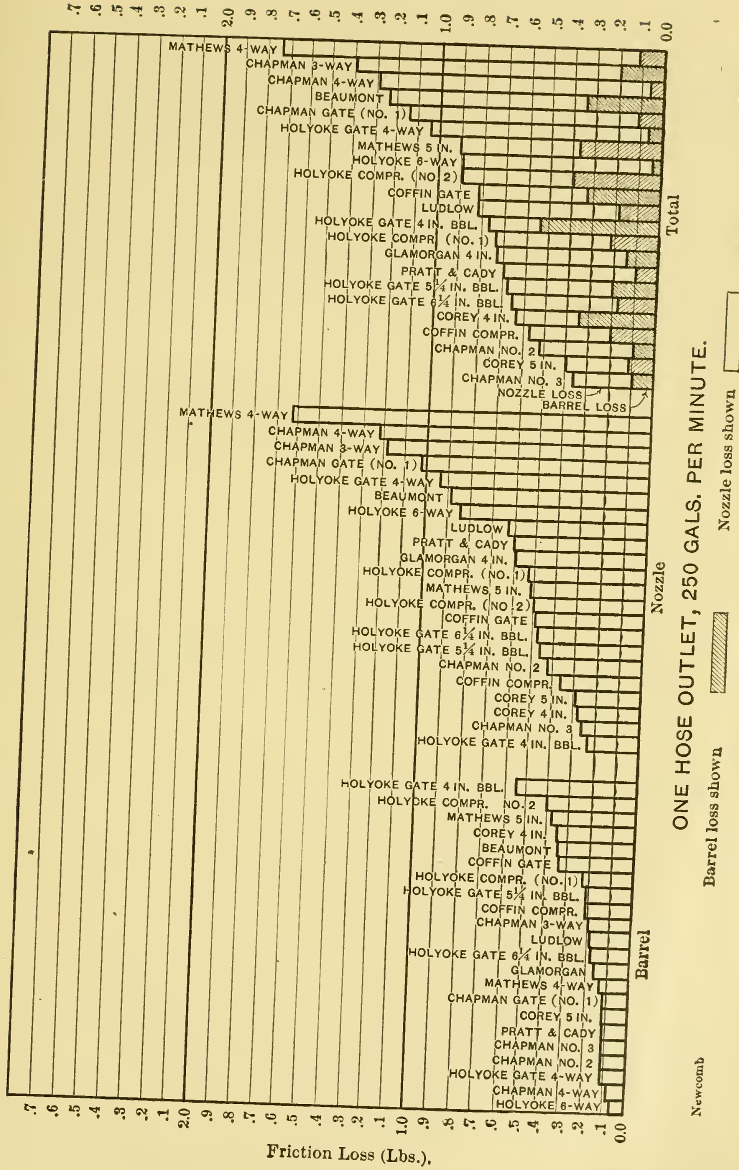

ONE HOSE OUTLET, 250 GALS. PER MINUTE.
Barrel loss shown
Nozzle loss shown
Total
MATHEWS 4-WAY
CHAPMAN 3-WAY
CHAPMAN 4-WAY
BEAUMONT
CHAPMAN GATE (NO. 1)
HOLYOKE GATE 4-WAY
MATHEWS 5 IN.
HOLYOKE 6-WAY
HOLYOKE COMPR. (NO 2)
COFFIN GATE
LUDLOW
HOLYOKE GATE 4 IN. BBL.
HOLYOKE COMPR (NO. 1)
GLAMORGAN 4 IN.
PRATT & CADY
HOLYOKE GATE 5¼ IN. BBL.
HOLYOKE GATE 6¼ IN. BBL.
COREY 4 IN.
COFFIN COMPR.
CHAPMAN NO. 2
COREY 5 IN.
CHAPMAN NO. 3
NOZZLE LOSS
BARREL LOSS
Nozzle
MATHEWS 4-WAY
CHAPMAN 4-WAY
CHAPMAN 3-WAY
CHAPMAN GATE (NO. 1)
HOLYOKE GATE 4-WAY
BEAUMONT
HOLYOKE 6-WAY
LUDLOW
PRATT & CADY
GLAMORGAN 4 IN.
HOLYOKE COMPR. (NO. 1)
MATHEWS 5 IN.
HOLYOKE COMPR. (NO 2)
COFFIN GATE
HOLYOKE GATE 6¼ IN. BBL.
HOLYOKE GATE 5¼ IN. BBL.
CHAPMAN NO. 2
COFFIN COMPR.
COREY 5 IN.
COREY 4 IN.
CHAPMAN NO. 3
HOLYOKE GATE 4 IN. BBL.
Barrel
HOLYOKE GATE 4 IN. BBL.
HOLYOKE COMPR. NO. 2
MATHEWS 5 IN.
COREY 4 IN.
BEAUMONT
COFFIN GATE
HOLYOKE COMPR. (NO. 1)
HOLYOKE GATE 5¼ IN. BBL.
COFFIN COMPR.
CHAPMAN 3-WAY
LUDLOW
HOLYOKE GATE 6¼ IN. BBL.
GLAMORGAN
MATHEWS 4-WAY
CHAPMAN GATE (NO. 1)
COREY 5 IN.
PRATT & CADY
CHAPMAN NO. 3
CHAPMAN NO. 2
HOLYOKE GATE 4-WAY
CHAPMAN 4-WAY
HOLYOKE 6-WAY
Friction Loss (Lbs.).
Newcomb

FIG. 47.

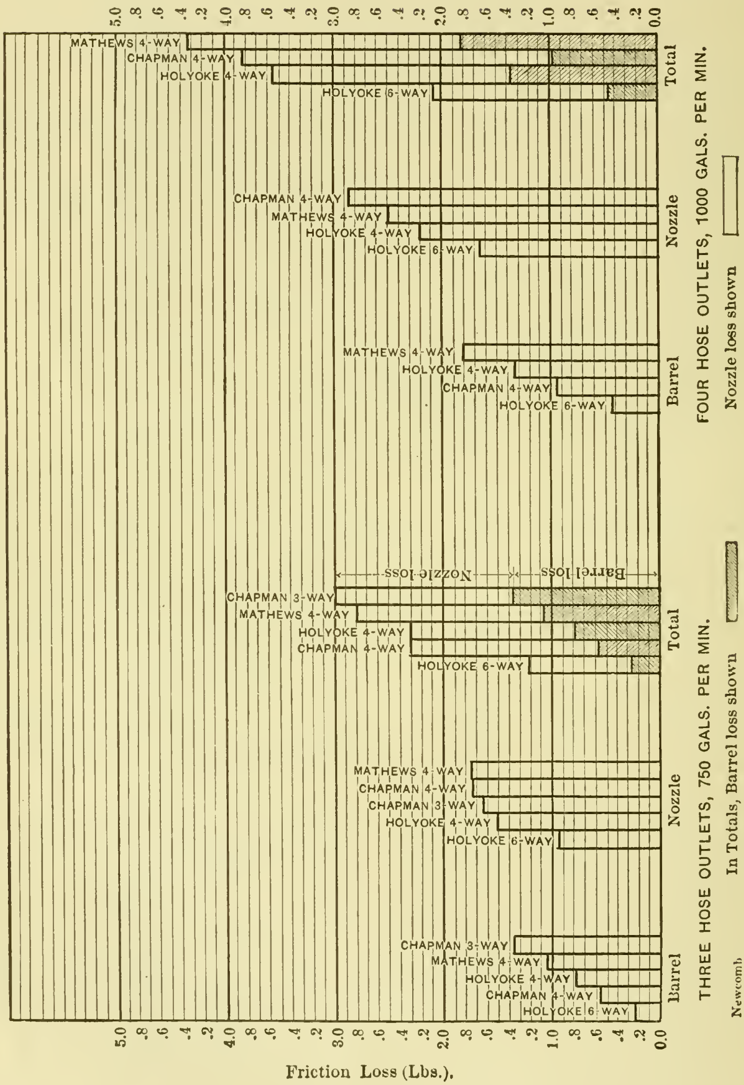
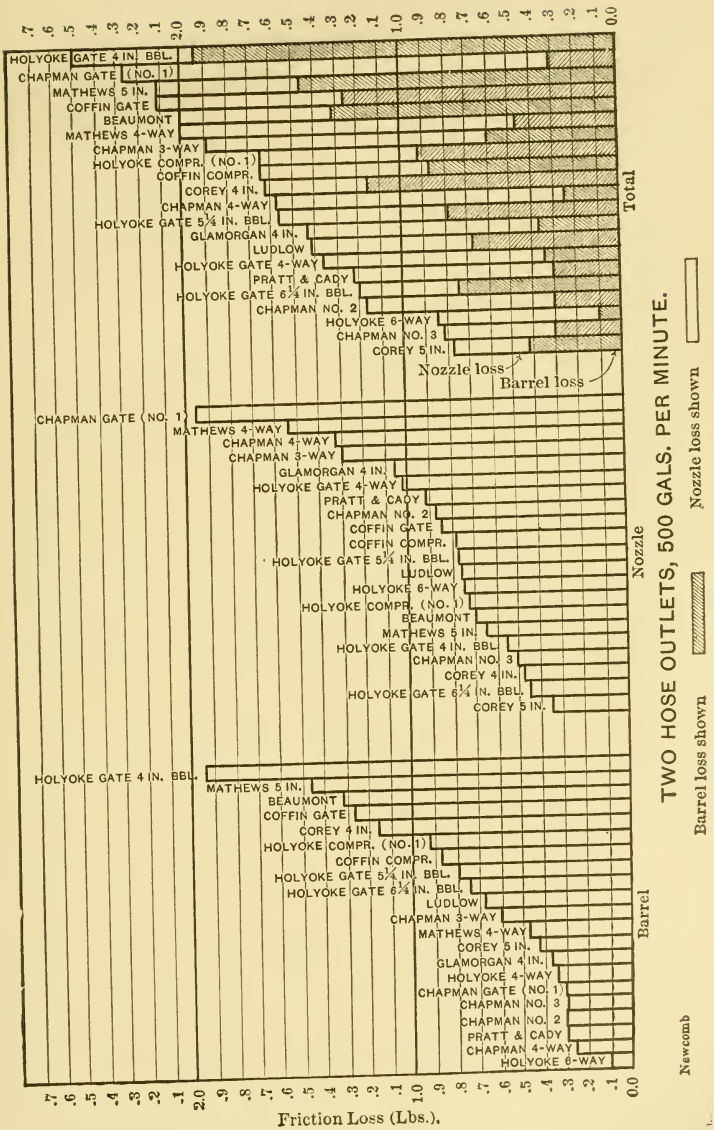

FOUR HOSE OUTLETS, 1000 GALS. PER MIN.
Total
MATHEWS 4-WAY
CHAPMAN 4-WAY
HOLYOKE 4-WAY
HOLYOKE 6-WAY
Nozzle
CHAPMAN 4-WAY
MATHEWS 4-WAY
HOLYOKE 4-WAY
HOLYOKE 6-WAY
Barrel
MATHEWS 4-WAY
HOLYOKE 4-WAY
CHAPMAN 4-WAY
HOLYOKE 6-WAY
Nozzle loss shown
THREE HOSE OUTLETS, 750 GALS. PER MIN.
Nozzle loss
Barrel loss
Total
CHAPMAN 3-WAY
MATHEWS 4-WAY
HOLYOKE 4-WAY
CHAPMAN 4-WAY
HOLYOKE 6-WAY
Nozzle
MATHEWS 4-WAY
CHAPMAN 4-WAY
CHAPMAN 3-WAY
HOLYOKE 4-WAY
HOLYOKE 6-WAY
Barrel
CHAPMAN 3-WAY
MATHEWS 4-WAY
HOLYOKE 4-WAY
CHAPMAN 4-WAY
HOLYOKE 6-WAY
In Totals, Barrel loss shown
Newcomb
5.0 .8 .6 .4 .2 4.0 .8 .6 .4 .2 3.0 .8 .6 .4 .2 2.0 .8 .6 .4 .2 1.0 .8 .6 .4 .2 0.0
Friction Loss (Lbs.).

FIG. 48.



TWO HOSE OUTLETS, 500 GALS. PER MINUTE.

FIG. 49.

DISCUSSION OF RESULTS.

The data and results being presented in full give ample chances for complete studies. Under these conditions detailed comparisons of the different hydrants have not been considered necessary or wholly desirable. A few general features may, however, be considered to advantage.

Barrel Loss. The best point of comparison for the two-way hydrants is with two hose outlets in use and 500 gallons per minute flowing, as this represents the full normal capacity of the hydrant. Similar full-capacity points should be taken in comparing the larger hydrants.

To make clear the composition of the so-called barrel loss, the following table has been made and shows about how much of this loss occurs in the barrels proper. The figures show at once that a large part of the loss must be in the gate and the sharp turn just beyond it, thus suggesting where to look for explanation for part of the large difference found. The distance from the center of the main gate to the center of the nozzles is, on the average hydrant, about 6½ feet. The following table gives approximately the friction loss in 6½ feet of clean, straight cylindrical pipe of the same smoothness as the inside of the average hydrant barrel.

Friction Loss in 6½ Feet. Pounds per Square Inch.

Nominal Diameter of Pipe (Inches).	Gallons per Minute Flowing. 250.	500.	750.	1,000.
4	0.11	0.41	0.62	1.54
5	0.037	0.13	0.22	0.50
6	0.012	0.059	0.098	0.21
8	0.004	0.016	0.034	0.058

The table was made up from tests on ordinary new clean wrought-iron pipe with 25 per cent. added to the wrought-iron pipe figures for the somewhat greater roughness of the inside of the average hydrant casting. The 25 per cent. was an assumption based on general experience with pipes of various degrees of roughness.

Comparing on the pyramid diagrams hydrants having two 2½-inch outlets, the difference in barrel losses is seen to be large.

It is at once apparent that the 4-inch gate * and barrel are too small for a two-stream hydrant. A 4-inch barrel and a discharge of 500 gallons per minute mean a velocity of about 13 feet per second, so that a short length of barrel with the smoothest sort of a turn at the bottom develops an unreasonable loss, and this loss becomes still larger with the ordinary gate arrangement and sharp turn-bend.

Comparing further the hydrants which have about the same general dimensions, the difference in loss is considerable. This must be accounted for largely by differences in the design of the gate and the water passages in the immediate vicinity. Sharp corners, restricted sections, and sudden changes in the area of the passages all tend to produce eddyings, which use up pressure.

Nozzle Loss. As already stated, the nozzle losses are pure friction losses, full correction for velocity having been made. To compare the outlets themselves, looking at them as simple nozzles, the condition with one stream on and 250 gallons per minute flowing is the best point. Studying the losses and the cuts together, the effect of sharp, jagged corners at the outlets is immediately seen, and the very material reduction in loss by even a slight rounding of the outlet is apparent.

Considering the hydrant as a whole, by taking the conditions, with all of the outlets in use, it is seen that the average nozzle loss when all are in use is generally greater than with a single outlet in use. Separate tests on the two outlets of several hydrants showed a difference in loss with the same quantity flowing. This would account for a small part of the difference between loss with one outlet in use and with all outlets in use. Most of the difference is, however, undoubtedly due to the increase in choking and eddying effects at the top of the hydrant with the higher velocities. A part of this is due to reactions from the eddies at the outlets, and a part to the construction of the hydrant head.

The somewhat high losses with the Beaumont hydrant, considering the rounding outlets, is probably due to the fact that

* It was desired to have tests on some 4-inch-barrel hydrants to make the data complete, though most of the manufacturers would in general furnish larger barrels for two outlets. The 4-inch hydrant is, however, occasionally used.

the gage connection was necessarily several inches below the outlet, so that there was considerable length between the gage connection and the outlet, in which length some ordinary friction loss would occur.

Total Losses. The total-loss pyramid shows the relative obstruction caused by the different hydrants taken as a whole. The part of this due to the barrel has been cross-hatched and the part due to the nozzle left white, thus showing at a glance the relation of the two factors making up the total loss.

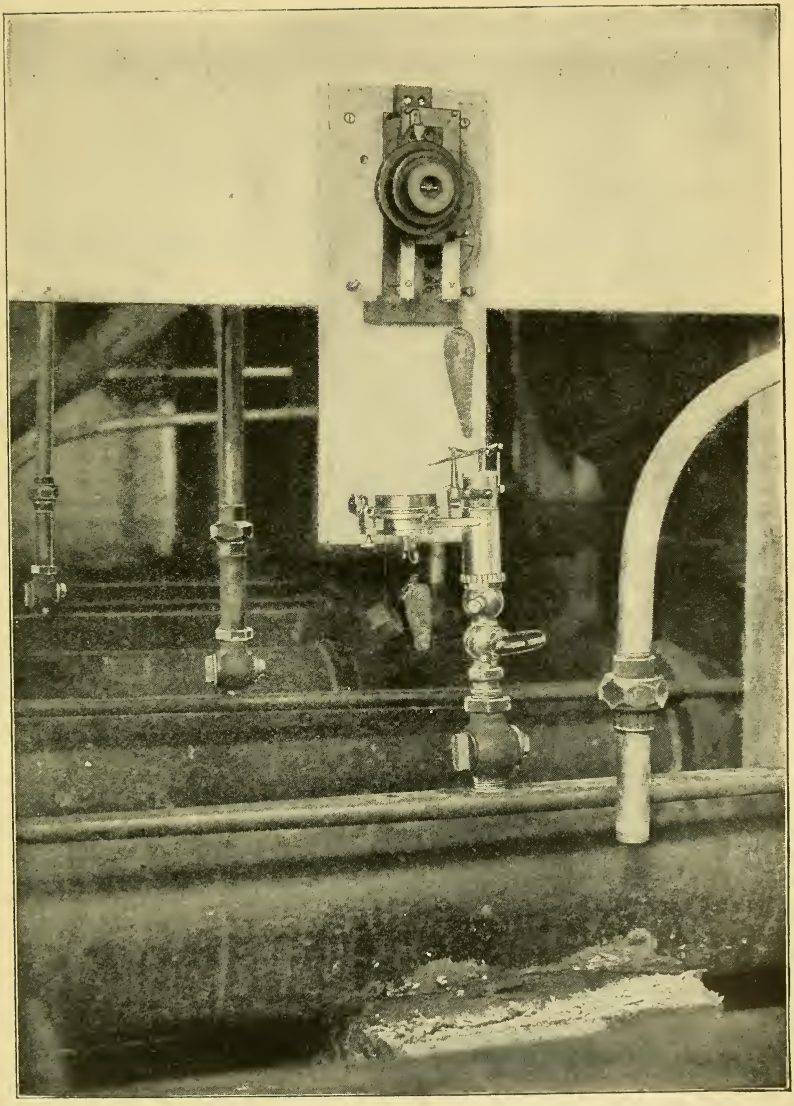
It is desirable that the waste of pressure through a hydrant should be as small as it is practicable to make it. In high-pressure systems the losses found for the average hydrants are perhaps tolerable, but in lower-pressure systems — and many systems having a nominally high pressure become low under heavy drafts — every avoidable loss is objectionable. In the hydrants without independent gates a simple rounding of the corners of the core at the outlet will make a material improvement in the nozzle losses. Reduction of loss for independent gate hydrants is more difficult, but some improvement is probably possible without serious trouble. The fact that some makers have found out how to reduce the barrel losses, so called, to comparatively small amounts is good working ground for improvements in those hydrants now having rather large losses.

It is not to be understood that this friction loss is the criterion for a perfect hydrant. Certainty of action under all conditions is of the greatest importance, but, other things being equal, the hydrant having the smallest total friction loss when working at its full capacity is the best.

WATER-HAMMER TESTS.

To get some measure of the water-hammer effect, caused when a hydrant is quickly shut down, the following apparatus was devised:

An indicator was attached to the connection in the 6-inch hydrant inlet which had been used by the U-tubes. The drum of this indicator was operated by clockwork in the manner shown in Plate III, and was so adjusted as to revolve once in from three and a half to four minutes. A small weight and cord kept



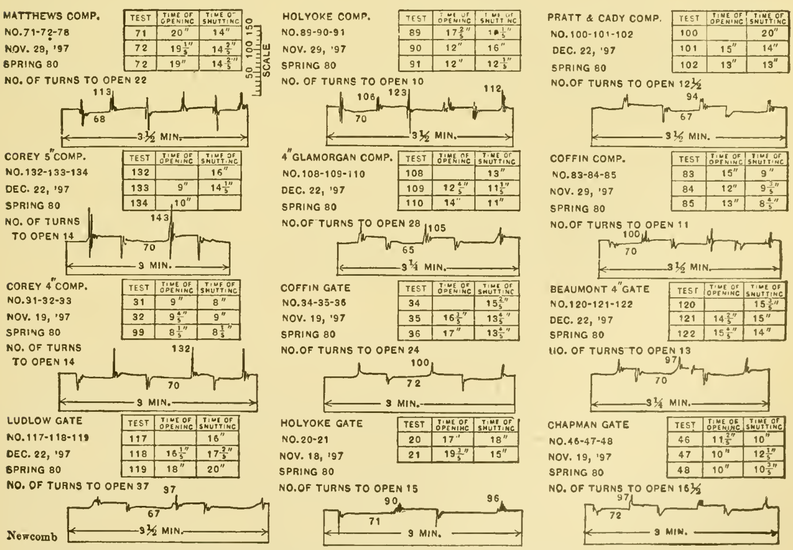
Apparatus for Taking Water-Hammer Cards.

the pencil in contact with the paper during the taking of a card. Plate II, Fig. 2, also shows the rig on a smaller scale.

Two lines of hose were taken from the hydrant under test to the meter nozzle, and the hydrant gate opened wide. A $1\frac{3}{4}$-inch nozzle was used and the pressure set at about 43 pounds by adjusting the gate on the inlet pipe at the entrance to the building. This gave a discharge of approximately 600 gallons per minute, which was considered a fair rate of flow for these tests.

At a given signal the indicator cock was opened, the clockwork set in motion, and time taken. After running steadily for about one fourth of a minute the hydrant valve was quickly closed; that is, it was closed as quickly as an active man could close it, using an ordinary hydrant wrench.

As soon as steady conditions were restored, the valve was as quickly opened again. This was repeated two to three times during the time that drum of indicator was in motion. Any variation of pressure caused by this closing or opening of the valve was recorded on the card. The time occupied in closing, and also



* Gate went hard near end of closing, preventing normal water-hammer action.

FIG. 50. WATER-HAMMER CARDS.

in opening, was taken by a stop-watch, so that some comparison can be made between the treatment given any one hydrant and another. Sample cards from the various tests have been picked out, grouped, and directly reproduced in Fig. 50. In getting this reproduction the delicate lines made by the pencil point of the indicator were carefully gone over with ink so as to get a card which could be photographed.

This method of measuring cannot show just what the actual pounds rise of pressure in any particular case would be, as this depends on the arrangement of piping supplying the hydrant, and the drafts of water in the system independent of the hydrant draft. It does, however, give a rough means of comparing the different hydrants.

The cards show that the gate hydrants give generally considerably less water-hammer than the compression type.*

It was stated in explanation of the large hammer effects found in one of the special type of compression hydrants that firemen demand a hydrant which will give the full pressure at the earliest possible moment, so that a quick movement was purposely designed. It is firmly believed that in the long run it will be very much better to insure the safety of water mains by avoiding heavy water-hammer effects than to gain a few seconds of time at the risk of crippling the distributing system, very likely at the critical point of a fire.

In several of the compression hydrants a vibrating effect will be noticed during the opening of the valve. This is apparently due to a chattering of the valve, and produces a rather undesirable water-hammer, as it is a series of quick, sharp blows.

CONSTRUCTION, STRENGTH, ETC.

Time prevented carrying on this part of the work as thoroughly as was desired, so that only partial results were obtained for

* The comparatively small hammer shown by the Coffin Compression is probably explained by the special double-beat valve, which is designed to give a more gradual closing than is ordinarily obtained with the compression type of gate.

The small hammer shown by the Pratt & Cady Compression is probably largely due to the fact that, when near the point of closing, the stream began to go hard, preventing a quick shutdown. The results are, therefore, not fairly comparable with the other hydrants. In the other hydrants the force required to open and close appeared about normal.

some of the hydrants, while on most of them a considerably further study of construction and general features would have been desirable. What data were obtained is shown in Table VI, about which the following explanations may be made:

Column 3. The inside volume of the hydrant is the volume between the main gate and the caps on the nozzles. This was obtained by filling the hydrant completely full of water and computing the volume from the weight of water.

Column 4. The time to drain the hydrant was taken from the instant the main gate was closed. Facts which developed as the tests progressed from the ordinary handling of the hydrants tended to show the desirability of having positive-motion drip-valves. Two of the hydrants had not positive drips, and in both of these the drips got out of order and failed to close when the main valve was open. The importance of having an absolutely reliable drip-valve, so as to reduce the chances of freezing to a minimum, must be apparent to every one.

Columns 5 and 6. The hydrostatic tests were made with an ordinary high-pressure hand pump, which is shown at one corner of the room in Plate II, Fig. 2. The aim was not to break anything, but to see how the hydrant would act with a considerable increase of pressure above the normal. Table VI shows the results in full.

Column 7. A broken or twisted valve stem is not an uncommon result of the excitement of a large fire. Sometimes a hydrant sticks, or a mistake is made in the direction to turn for opening or closing. Often in such cases, if one man cannot start the hydrant, two or more men take hold. In this connection it is somewhat surprising that so far as known no one has yet made a hydrant which is not liable to serious damage if a forcible attempt is made to turn it in the wrong direction, either opening or closing; something accomplishing what the ratchet on a stem-winding watch accomplishes seems possible and greatly preferable to the simple limit of breaking strength. Such a device might also give the fireman immediate evidence that he was wrong, thus saving time. A hydrant cannot be expected to stand unlimited abuse, but to get some idea of the ability of the hydrants to withstand such usage the following tests were made: Two ordinary men

TABLE VI.—CONSTRUCTION AND STRENGTH OF HYDRANTS.

1	2	3	4		5		6		7
NAME OF HYDRANT.	Weight of Hydrant.	Inside Volume of Hydrant.	Time Required to Drain.		HYDROSTATIC TEST OF MAIN VALVE.		HYDROSTATIC TEST OF HYDRANT BARREL.		Result of Test of Valve Stems.
					Pressure Put on.	Result.	Pressure put on.	Result.	
	lbs.	cu. ft.	m.	s.	lbs.		lbs.		
Beaumont	290	0.69	2	30	180	Valve tight.	300	Drip leaked very little	Stems twisted off.
Chapman No. 1	435	1.39	7	30	180	Pressure dropped in ½ min. 80 lbs.	150	Caps leaked.	Stem twisted out of shape.
" No. 2	425	1.44	7	15					
" No. 3	734	2.29	5	11					
Chapman 3-way	577	1.63	7	01					
" 4-way	580	2.24							
Coffin Gate	467	1.59	....	.....	180	Pressure dropped in 1 min. 80 lbs.	240	Caps leaked.	Not injured.
" Compression	506	1.44	7	30	180	Pressure dropped in 1 min. 75 lbs.	280	" "	Stem strained, but not broken.
Corey 4-in	418	1.55	2	20	180	Pressure dropped in 1 min. 80 lbs.	200	" "	
" 5-in	560	2.24	3	40	180	Pressure dropped in 40 secs. 80 lbs.	300	" "	Not injured.
Glamorgan 4-in	531	1.22	2	05	180	Valve tight.	280	" "	Top of stem broken off.
Holyoke Gate, 4-in	356	1.02							
Holyoke Gate, 6¼-in	500	2.16	9	00	180	Pressure dropped in 1 min. 80 lbs.	300	Caps leaked.	Stem twisted off.
" Compression No. 1	669	1.20	4	30	180	Pressure dropped in 1 min. 80 lbs.	220	" "	Bottom of hydrant pushed out.
" " No. 2	538	0.77							
" Gate, 4-way	580	2.24							
" " 6-way	....	....	31	06					
Ludlow	497	1.87	3	40	180		230	Caps leaked.	Stem twisted out of shape.
Mathews 5-in	750	1.42	5	30	180	Pressure dropped in 50 secs. 80 lbs.	280	Flange at bottom leaked	Top of stem broken off.
" 4-way	757	1.50							
Pratt & Cady	688	2.28	15	00	70	Valve leaked badly.	220	Caps leaked.	Yoke in bottom of hydrant broken.

were instructed to open each hydrant, using the regular hydrant wrench, which is 17 inches long, exerting their maximum strength in an effort to open the hydrant beyond its natural limit. If no injury resulted they closed the hydrant, exerting again their maximum strength after the hydrant was completely shut.

These tests, therefore, took the strength of two ordinary men using a wrench of definite length as the measure of the force applied. It is not exact in any way, but gives some results which, in a practical way, are somewhat useful.

In most instances some injury was done to the hydrant, the stem generally being the point to give way, though in one case the bottom of a hydrant was actually pushed out by attempting to open it beyond its natural limit.

Durability and Repair. Time did not give a chance for any complete tests on the durability of the working parts of the hydrant, but starting with the assumption that a hydrant might be opened on an average ten times a year, and should be good for a service of twenty years, each hydrant was opened and closed two hundred times. No special derangement of wear resulted, except in two cases, in which the stuffing-box nut on top of the hydrants showed a tendency to work loose.

In a number of the hydrants the design has been made with the idea of facilitating repairs. In some cases this resulted in considerable restriction to the water ways. It is believed that in most cases, by keeping the desirability of free water ways in mind, ability to make quick repairs can be combined with smooth, free waterways. In this connection the friction-loss tests will be of value in showing what can be done and what should be avoided.

METER TESTS.

As previously stated, the two large meters used in the open-butt tests were calibrated by the nozzles, the quantities by the nozzles being assumed to be correct. This calibration work was done in connection with the regular tests, but has been tabulated independently, and the data in full are given in Tables VII and VIII. From these data a curve was plotted for each meter, with nozzle readings for one coördinate and meter readings for the

other (see Fig. 51). From this curve the corrected meter readings were taken directly in working up the open-butt tests.

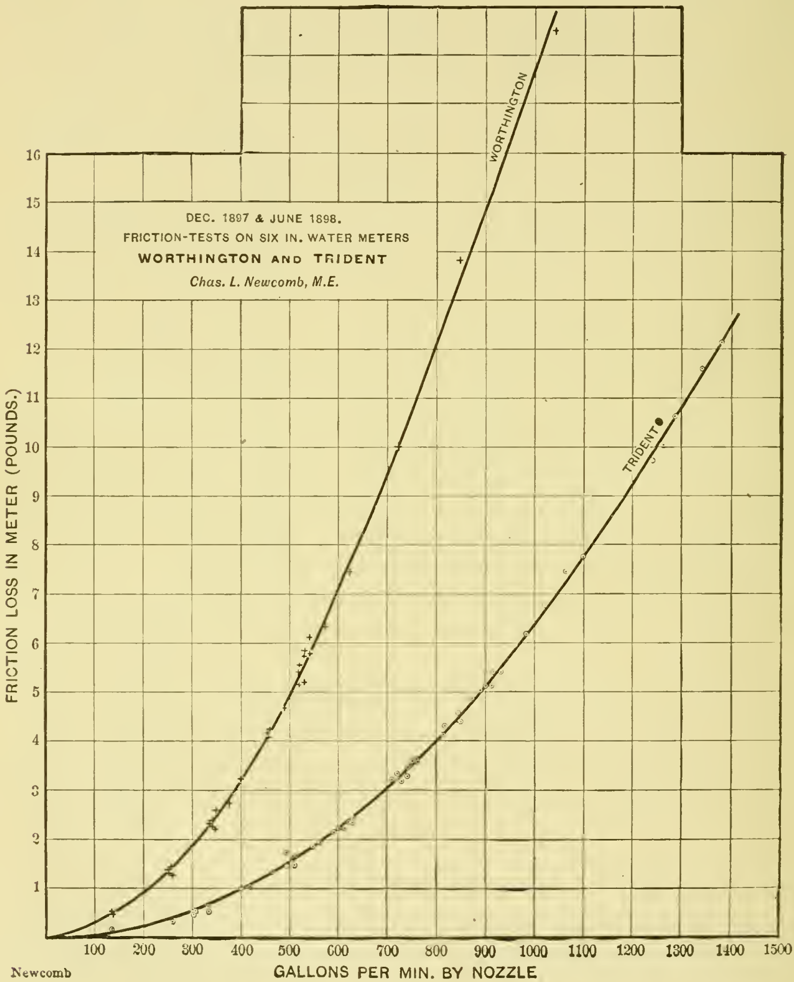


Fig. 51.

The arrangement of the apparatus gave an excellent opportunity to determine the obstruction to the flow of water; that is, the friction loss caused by the meters. As this may become an

important feature where handling large quantities of water, and as data on large meters with high rates of flow are not very complete, a few tests were made to determine this loss. The method of testing followed was similar to that employed in the series of meter tests reported by Mr. E. V. French in the JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.* A gage connection

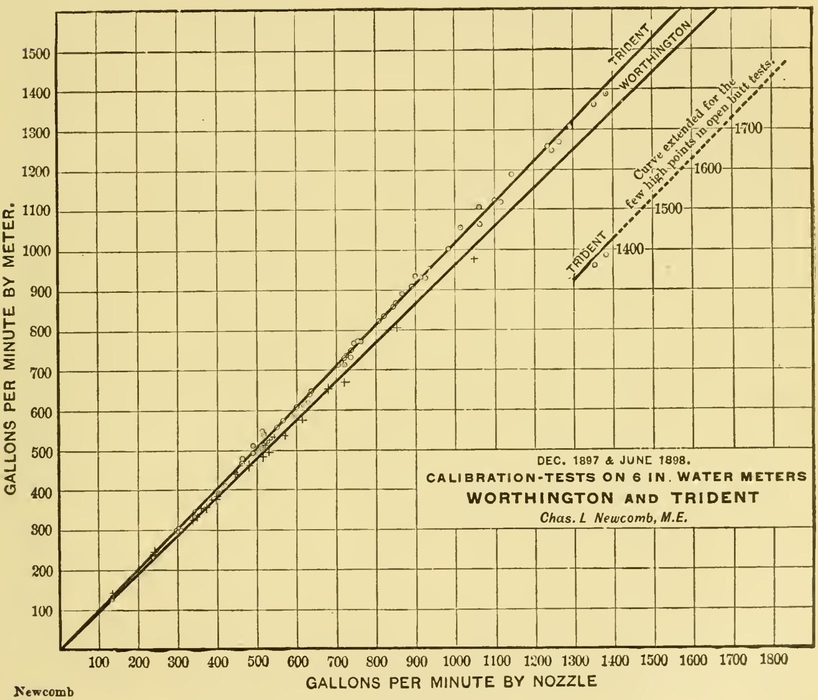


FIG. 52.

was tapped into the 6-inch pipe at each side of the meter and a short distance from it, the connection being arranged the same as those at the inlet pipe of the hydrants. Between these two connections a mercury U-gage was attached, and the friction loss caused by the meter with various rates of flow was read

* "Losses of Pressure Caused by Meters in Factory Fire Supplies," JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, vol. XXII, No. 2.

directly from this gage. The loss in the short lengths of the 6-inch pipe between the gage connections and the meter is included in the meter loss, as it was too small to be of practical importance. These data also appear in full in Tables VII and VIII, and the results have been plotted on Fig. 52, with the gallons per minute as one coördinate and the losses in pressure in pounds as the other.

The question is sometimes raised as to what would happen if the moving parts of a meter became blocked, an accident which may happen where a fish-trap is not provided with the meter, and which is a possibility under some conditions even where a fish-trap is used. After the hydrant tests were completed, a few experiments in this line were made with the Neptune meter, the owners having kindly consented that any sort of tests should be made with it, regardless of the results. The cover was removed and wooden wedges inserted, so as to hold the disk in various positions. It was found that it could be blocked so that almost no water could go through it, and that any degree of obstruction between this and a free opening could be obtained. With the meter blocked in various positions, full water pressure was turned on behind it to see if anything would be broken or sprung; and when in the position where practically no water got through the meter, the pressure warped the disk, though not enough to appreciably increase the flow of water.

TABLE VII.

Tests on 6-inch Worthington Water Meter.

1	2	3		4	5	6	7	8	9	10
Test No.	Date of Test.	Duration of Test.		Diam. of Nozzle. Inches.	Pressure at Nozzle. Corrected Pounds.	Gallons per Minute by Nozzle.	Total Cubic Feet by Meter.	Gallons per Minute by Meter.	Diff. in Gals. per Min. Nozzle as Standard (6–8).	P'ds Loss between Gauge Con'ctions eq'ls Meter Loss.
		m.	s.							
488	Dec. 10, 1897	11	$01\frac{2}{5}$	$\frac{3}{4}$	66.70	135	200	135	0	
489	"	11	$44\frac{1}{5}$	$1\frac{1}{8}$	46.49	255	400	255	0	1.29
490	"	11	29	$1\frac{1}{4}$	53.18	340	500	326	+14	2.22
491	"	10	$01\frac{1}{5}$	$1\frac{3}{4}$	24.14	458	600	448	+10	4.24
492	"	10	$11\frac{2}{5}$	2	17.44	518	700	514	+ 4	5.41
493	"	10	24	$1\frac{1}{4}$	64.60	375	500	360	15	2.75
494	"	10	$42\frac{3}{5}$	$1\frac{3}{4}$	30.34	514	700	488	26	5.18
495	"	10	$08\frac{1}{5}$	$1\frac{3}{4}$	44.63	623	800	590	33	7.45
496	"	10	$55\frac{3}{5}$	2	33.84	722	1,000	684	38	10.00
497	"	10	$12\frac{3}{5}$	$2\frac{1}{2}$	16.87	848	1,100	806	42	13.80
498	"	10	$40\frac{2}{5}$	$2\frac{1}{2}$	25.53	1,044	1,400	981	63	18.50
499	"	11	12	$\frac{3}{4}$	65.66	134	200	134	0	0.50
500	"	11	$52\frac{1}{3}$	$1\frac{1}{8}$	46.07	254	400	252	2	1.31
501	Dec. 11, 1897	11	$38\frac{2}{5}$	$1\frac{1}{4}$	51.77	336	500	321	15	2.32
502	"	13	$26\frac{3}{5}$	$1\frac{3}{4}$	23.87	457	800	445	12	4.17
503	"	10	$12\frac{3}{5}$	2	17.23	516	700	512	4	5.55
509	"	11	11	$\frac{3}{4}$	65.68	134	200	134	0	0.50
510	"	11	$53\frac{1}{5}$	$1\frac{1}{8}$	45.73	254	400	252	2	1.40
511	"	11	$32\frac{4}{5}$	$1\frac{1}{4}$	52.96	340	500	323	7	2.29
512	"	10	$06\frac{4}{5}$	$1\frac{3}{4}$	23.95	457	600	444	13	4.18
513	"	10	02	2	18.36	531	700	522	9	5.85
519	Dec. 13, 1897	11	11	$\frac{3}{4}$	65.7	134	200	134	0	0.50
520	"	11	$49\frac{4}{5}$	$1\frac{1}{8}$	45.94	254	400	253	1	1.41
521	"	11	$30\frac{3}{5}$	$1\frac{1}{4}$	53.25	340	500	324	16	2.39
522	"	11	$47\frac{1}{5}$	$1\frac{3}{4}$	23.65	455	700	444	11	4.18
523	"	11	$28\frac{1}{5}$	2	18.3	530	800	522	8	5.75
524	"	11	15	$\frac{3}{4}$	64.78	133	200	133	0	.54
525	"	11	$52\frac{1}{5}$	$1\frac{1}{8}$	46.00	254	400	252	2	1.45
526	"	11	33	$1\frac{1}{4}$	53.08	340	500	324	16	2.26
527	"	10	$08\frac{3}{5}$	$1\frac{3}{4}$	23.86	456	600	443	13	4.08
528	"	11	$18\frac{2}{5}$	2	18.69	537	800	529	8	5.80
591	Dec. 16, 1897	11	19	2	18.87	540	800	529	11	6.11
592	"	11	$01\frac{1}{5}$	$1\frac{3}{4}$	14.00	350	500	341	9	18.60
593	"	11	$34\frac{1}{5}$	$1\frac{3}{4}$	18.2	398	600	386	12	3.24
594	"	11	$22\frac{4}{5}$	$1\frac{3}{4}$	26.9	485	700	462	23	4.65
595	"	10	$28\frac{4}{5}$	$1\frac{3}{4}$	32.0	528	700	498	30	5.20
596	"	11	$06\frac{1}{5}$	$1\frac{3}{4}$	37.2	570	800	539	31	6.31
609	"	5	56	2	9.76	388	300	378	10	......
610	"	5	$45\frac{3}{5}$	2	29.76	578	500	650	28	......
611	"	11	45	$1\frac{3}{4}$	18.23	398	600	382	16	......
612	"	11	$21\frac{2}{5}$	$1\frac{3}{3}$	27.04	485	700	461	24	......

TABLE VIII.

Test on 6-inch Trident Water Meter.

1	2	3		4	5	6	7	8	9	10
Test No.	Date of Test.	Durat'n of Test.		Diam. of Nozzle. Inches.	Pres're at Nozzle Cor'ted Lbs.	Gallons per Minute by Nozzle.	Total Cubic Feet by Meter.	Gallons per Min. by Meter.	Diff. in Gals. per Min. Nozzle as Standard (6-8).	Pounds Loss between Gauge Connections Equals Meter Loss.
		m.	s.							
875	June 2, 1898.	5	$05\frac{2}{5}$	$\frac{3}{4}$	66.04	135	90	130	+ 5	....
876	" " "	5	$02\frac{4}{5}$	$1\frac{1}{8}$	44.41	250	170	247	+ 3	....
877	" " "	5	$09\frac{2}{5}$	$1\frac{1}{4}$	50.31	332	230	328	+ 4	....
878	" " "	5	$01\frac{4}{5}$	$1\frac{3}{4}$	24.52	463	320	471	– 8	....
879	" " "	5	$00\frac{4}{5}$	2	16.93	511	360	530	– 19	1.68
880	" " "	4	$59\frac{2}{5}$	$1\frac{1}{4}$	41.62	301	200	296	+ 5	0.47
881	" " "	4	$57\frac{4}{5}$	$1\frac{3}{4}$	29.53	507	340	507	0	1.50
882	" " "	4	$59\frac{2}{5}$	$1\frac{3}{4}$	44.52	623	420	619	+ 4	2.32
883	" " "	5	$01\frac{1}{5}$	2	33.26	708	490	723	– 15	3.20
884	" " "	5	01	$2\frac{1}{2}$	15.52	807	560	826	– 19	4.10
885	" " "	1	$59\frac{2}{5}$	$2\frac{1}{2}$	19.60	916	250	929	– 13	5.40
886	" " "	1	$59\frac{3}{5}$	2	35.35	738	200	741	– 3	3.30
887	" " "	1	$59\frac{4}{5}$	$1\frac{3}{4}$	39.99	590	160	592	– 2	2.16
888	" " "	2	$59\frac{1}{5}$	$1\frac{3}{4}$	18.43	400	160	395	– 5	1.02
889	" " "	2	$12\frac{4}{5}$	$1\frac{1}{4}$	41.52	300	90	301	– 1	0.57
890	" " "	2	$02\frac{1}{5}$	$1\frac{3}{4}$	29.29	506	140	507	– 1	1.53
891	" " "	2	$02\frac{1}{5}$	$1\frac{3}{4}$	43.00	612	170	615	– 3	2.21
892	" " "	2	02	2	33.56	720	200	727	– 7	3.23
893	" " "	2	$02\frac{1}{5}$	$2\frac{1}{2}$	15.72	819	230	835	– 16	4.30
894	" " "	2	05	2	19.47	549	160	561	– 12	1.88
895	" " "	2	$05\frac{4}{5}$	2	34.74	731	210	745	– 14	3.46
896	" " "	2	$05\frac{3}{5}$	$2\frac{1}{2}$	17.85	873	250	893	– 20	4.89
897	" " "	2	$00\frac{3}{5}$	$2\frac{1}{2}$	22.65	982	270	1,001	– 19	6.18
898	" " "	2	31	2 & 1	23.78 24.12	752	260	772	– 20	3.57
899	" " "	1	$31\frac{2}{5}$	2 & 1	34.05 34.87	898	190	929	– 31	5.10
900	" " "	1	$33\frac{1}{5}$	$2\frac{1}{2}$ & $1\frac{1}{8}$	18.32 22.07	1,063	230	1,104	– 41	7.49
901	" " "	1	$30\frac{1}{5}$	$2\frac{1}{2}$ & $1\frac{1}{4}$	20.67 21.25	1,156	240	1,194	– 38	8.77
902	" " "	2	$29\frac{3}{5}$	$2\frac{1}{2}$ $1\frac{1}{8}$ & $1\frac{1}{8}$	17.50 24.42	1,237	330	1,260	– 23	9.67
903	" " "	2	$30\frac{4}{5}$	$2\frac{1}{2}$ $1\frac{1}{8}$ & $1\frac{1}{8}$	13.98 19.89	1,109	380	1,126	– 17	8.29
904	" " "	1	32	$2\frac{1}{2}$ $1\frac{1}{4}$ & $1\frac{1}{8}$	....	1,277	270	1,315	– 18	10.90
1,197	June 21, 1898.	3	$18\frac{2}{5}$	$\frac{3}{4}$	65.31	134	60	136	– 2	0.14
1,198	" " "	3	$09\frac{3}{5}$	$1\frac{1}{8}$	47.16	258	110	260	– 2	0.32
1,199	" " "	3	$05\frac{3}{5}$	$1\frac{1}{4}$	51.51	334	140	338	– 4	0.66
1,200	" " "	3	$07\frac{3}{5}$	$1\frac{3}{4}$	24.61	463	200	478	– 15	1.33
1,201	" " "	3	05	2	16.65	507	220	534	– 27	1.66
1,202	" " "	3	$13\frac{1}{5}$	$1\frac{1}{4}$	41.47	302	130	302	0	0.55
1,203	" " "	3	$05\frac{2}{5}$	$1\frac{3}{4}$	28.34	494	210	508	– 14	1.47
1,204	" " "	3	$02\frac{3}{5}$	$1\frac{3}{4}$	45.36	629	260	639	– 10	2.31
1,205	" " "	3	02	2	34.06	725	300	740	– 15	3.20
1.206	" " "	3	$02\frac{2}{5}$	$2\frac{1}{2}$	16.59	843	350	861	– 18	4.58
1,207	" " "	3	$03\frac{3}{5}$	$1\frac{3}{4}$	19.14	417	170	416	+ 1	1.05
1,208	" " "	2	$05\frac{2}{5}$	$1\frac{3}{4}$	41.10	600	170	608	– 8	2.22
1,209	" " "	3	$05\frac{2}{5}$	2	37.63	761	320	775	– 14	3.57
1,210	" " "	3	$04\frac{2}{5}$	$2\frac{1}{2}$	20.21	930	390	949	– 19	5.40
1,211	" " "	3	$07\frac{3}{5}$	2	20.44	561	240	574	– 13	1.97
1,212	" " "	3	$03\frac{1}{5}$	2	35.87	745	310	759	– 14	3.49
1,213	" " "	3	$03\frac{1}{5}$	$2\frac{1}{2}$	18.49	889	370	906	– 17	5.02
1,214	" " "	3	$01\frac{3}{5}$	$2\frac{1}{2}$	25 53	1,023	430	1,063	– 40	6 77
1,215	" " "	3	14	$1\frac{1}{4}$	42.27	307	130	301	+ 6	0.56
1,216	" " "	3	$00\frac{2}{5}$	$1\frac{3}{4}$	27.99	494	200	498	– 4	1.73
1,217	" " "	3	$01\frac{4}{5}$	$1\frac{3}{4}$	45.59	630	260	642	– 12	2.44
1,218	" " "	3	$03\frac{4}{5}$	2	33.61	720	300	732	– 12	3.30
1,219	" " "	3	01	$2\frac{1}{2}$	16.86	849	350	868	– 19	4.40
1,220	" " "	2	$30\frac{3}{5}$	2 & 1	23.83 26.32	759	260	775	– 16	3.60
1,221	" " "	2	$24\frac{3}{5}$	2 & 1	34.23 38.33	910	320	929	– 19	5.13
1,222	" " "	2	$31\frac{2}{5}$	$2\frac{1}{2}$ & $1\frac{1}{8}$	19.11 27.30	1,100	380	1,126	– 26	7.77
1,223	" " "	2	$33\frac{2}{5}$	$2\frac{1}{2}$ & $1\frac{1}{4}$	22.86 29.22	1,243	430	1,256	– 13	9.70
1,224	" " "	2	$31\frac{2}{5}$	$2\frac{1}{2}$ & $1\frac{3}{8}$	22.31 24.95	1,264	430	1,275	– 11	10.01
1,225	" " "	2	31	$2\frac{1}{2}$ $1\frac{1}{8}$ & $1\frac{1}{8}$	18.91 26.90	1,292	440	1,308	– 16	10.60
1,226	" " "	2	$31\frac{2}{5}$	$2\frac{1}{2}$ $1\frac{1}{8}$ & $1\frac{1}{8}$	20.56 29.57	1,346	460	1,364	– 18	11.56
1,227	" " "	2	$31\frac{3}{5}$	$2\frac{1}{2}$ $1\frac{1}{4}$ & $1\frac{1}{4}$	19.56 25.32	1,387	470	1,391	– 4	12.13
1,228	" " "	2	$30\frac{3}{5}$	$2\frac{1}{2}$ $1\frac{1}{4}$ & $1\frac{1}{4}$	11.45 15.25	1,065	360	1,073	– 8	7.47

DISCUSSION.

President John C. Whitney. This paper of Mr. Newcomb, which represents an extraordinary amount of thought and labor, is now open to discussion.

Mr. Newcomb, I should like to inquire what period of time was necessary in order to bring about these results which you have tabulated.

Mr. Newcomb. You mean, what period the tests covered?

The President. Yes.

Mr. Newcomb. Something like a year and a half, although they were not carried on continuously during that time.

The President. Mr. Stacy, we should like to hear from you on the subject of fire hydrants, in reference to this paper especially.

Mr. George A. Stacy.* Mr. President, I don't know as I am prepared. I ought to be; we have had the paper long enough.

The President. You don't need to be.

Mr. Stacy. It brings out one point, I think, that in the number of years we have been constructing hydrants there hasn't been much of an effort made to reduce the friction in the hydrant by giving it easier water ways, except in two or three instances.

There are various points about hydrants that are not touched on, as this paper pertains largely to the important question of friction losses.

I think that this paper brings out the fact that hydrants are made with a large factor of safety. I know of a place where they have used an abnormally long hydrant wrench and a 3-foot piece of pipe. I asked the boys what they were doing with it, and they said, "We open our hydrants with that." They said, "Two fellows get hold of that, and if they can't open it, three of us get hold of it." [Laughter.] This was a number of years ago. At the present time they do not have that trouble. I make that statement just as they made it to me, and perhaps they made it a little strong. I know they had considerable trouble in opening hydrants, and they used considerable power; but I do not think the trouble was altogether with the hydrant construction.

Of course we have often seen a fireman try to open a hydrant

* Superintendent of Water Works, Marlboro, Mass.

the wrong way, and I don't think that is anything remarkable. A man in the volunteer fire department jumps out of bed and rushes to a fire, and he forgets which way the hydrant opens, — in the excitement of the moment he doesn't stop to think. But it shows that it generally takes more than one man to break the hydrants that are made to-day.

Another thing is the mechanical construction of the hydrants. I think there is a wide range of workmanship in the different hydrants. My experience is that there is lots of work done in the foundry that ought to be done in the machine shop on a good many hydrants. I have found, in my experience, hydrants where the fits, as I call them, were made in the foundry with cores that should be made in the machine shop with proper tools.

Speaking of the drip, it seems to me that we haven't made a great deal of progress and improvement. If we could have a drip that we could control from the surface, and actually know that it was working, and be able to close it permanently if we desired to, it would be an improvement in many localities.

And in regard to the frost case of hydrants: It seems to be considered by some that the function of the frost case is to protect the hydrant from frost. I never had that idea. The frost case is, as I understand it, for the purpose of keeping the frost from heaving the hydrant posts. We have hydrants made by some of our manufacturers where the frost case has no movement up or down; you can only revolve it around. I have got a few of them, and under these conditions the frost case is useless and iron thrown away.

This paper has brought out the necessity of better construction in the water ways of hydrants in order to get the maximum efficiency. It has also demonstrated that the hydrants that are in the market stand up to the rough usage that they sometimes get remarkably well.

We often hear of a non-freezing hydrant, because the drip is on a level or below the inlet pipe; this is not true under many conditions. I have perhaps six where the drip is a menace to the hydrant; they have to be plugged to keep the ground water out. I have one hydrant that is set under a bank on the sidewalk in the city, and in the spring, before the frost is out of the ground, in

March or the last of February, and sometimes during the winter, if the drip is open, the water will flow out of the nozzle from the water in the ground. Perhaps some of you have had that experience. Under these conditions, a drip that could be plugged without digging up the hydrant would be useful. I will say that the situation is where a bank 8 or 9 feet high is back of the hydrant, where the street has been cut down.

I think we should be more particular as to the mechanical construction, that is, the machine work that is put into the hydrant; I believe it pays. I have some hydrants that I think are as finely made as is required in that kind of work; they have been in the ground twenty-four years and a large per cent. of them have never cost a cent for repairs, and I have others that are not so well constructed, though just as strong, that have caused more or less trouble and expense.

I confess that I am not able to go into this thing very closely; there are others here who perhaps have studied this more than I have. It is a very interesting and instructive paper. I think that hydrant is something that can be improved, and it is up to us to pick out the points and tell what we want.

In regard to the nozzles, it has been the custom for a large majority of manufacturers to lead them in. I have hydrants that have never given me any trouble that are so constructed, and I have some that have caused considerable trouble and expense. I would not buy a hydrant of any kind to-day if the nozzle was not screwed into the barrel, unless forced to do so. Some object to that, saying that it may get loose. I think that could be prevented. I would require that every nozzle should be screwed in and so fastened that I could take it out, to replace or repair it, the same as any bolt or screw, and with as little trouble. I think we are all under great obligation to the City of Holyoke Water Board, who promoted, and to the men who assisted in making, these tests.

The President. We should like to hear from Mr. McInnes.

Mr. Frank A. McInnes.* I don't know, Mr. President, that I have much to say that is valuable. I feel very sure, however, that discussion on the fire hydrant is time well spent, as its full

*Assistant City Engineer, Boston, Mass.

share of blame has not always been given to the hydrant when needed pressure was not forthcoming. Unfortunately a hydrant of poor design fails when it is most needed; with a small flow and under ordinary conditions the loss, through its inefficiency, is perhaps unnoticed, but when the big fire comes along and a large flow is demanded, the test and the failure come; then valuable pressure in the main is simply wasted, thrown away in the hydrant; particularly is this true in the case of hydrants with steamer connections fitted with independent valves. One who has actually tested the friction loss in independent valves will quickly realize that an undue loss, an altogether inexcusable loss, may easily occur.

In Boston the conditions are somewhat severe. Two engines pumping 1 100 gallons per minute each, and nine pumping 750 gallons each, respond, with other smaller engines, to alarms down-town; these demands call for a hydrant capable of delivering about 2 500 gallons per minute without excessive loss, with 1 100 gallons per minute through at least one outlet, and that must be an independent valve outlet. (I think steamer outlets, particularly in city practice, should always be fitted with independent valves.)

To meet these conditions we started at the main, making the pipe leading to the hydrant 8 inches in diameter; we then considered the hydrant pot and made a new design for it to ease the flow as much as possible; then came the hydrant barrel, which was made practically 8 inches, with an ample water way at the bottom around the main valve; at this point our troubles began, because of the independent outlet through which we had to take 1 100 gallons per minute, without undue loss of head. Four different valves were designed and carefully tested with Bourdon gages, using the nozzle as a meter; that adopted is a simple gate valve inside the hydrant, working up and down in front of the outlet. The guides for the valve are cast in the shell of the hydrant itself, and when the valve is open there is absolutely nothing in the water way; it is entirely free.

Throughout the whole hydrant design we have tried to consider every little detail, avoiding sharp corners, projections, etc., wherever possible. For results, we get a total loss in the 4½-inch

valve on steamer outlet of 5 pounds, with 1 100 gallons per minute flowing; of this amount about 2 pounds represents the actual friction loss, the remainder, of course, being the head required to give the velocity. In the hydrant barrel and pot, with a flow of 2 500 gallons per minute, the loss was about 3½ pounds. We have concluded to be satisfied with these results, for the present at least, and consider that we have a hydrant in which the losses, under ordinary conditions, are almost negligible. In view of the fact that the demands of an adequate fire service require a much larger expenditure for main pipe than would be necessary for domestic service only, it is well worth while to be sure that the hydrant lead is large enough and that the hydrant itself is efficient.

THE PRESIDENT. We should like to hear from Mr. Brooks.

MR. EDWIN C. BROOKS.* I agree very thoroughly with what Mr. McInnes has said in this respect; that I think hydrants have been made, not with the care that they should have been made, not with the idea thoroughly in mind that the object was to get the water from the main to the nozzle of the hydrant with the least possible loss. And I think that it has been largely a matter of cost. We all know that when you get your figures for hydrants, as a general proposition the low figure wins; and that has been too much in evidence, not only with hydrants, but with other water-works appliances.

I wish that this Association might set the pace for not only a better hydrant in the way of construction, but a hydrant that was made with a thorough conception of all the abuse that it is liable or possible to get while in use.

Now we have in our city every department, I think, with the exception of the cemetery department, or the almshouse, using hydrants *ad lib.:* The sewer department is using hydrants for flushing sewers and for all kinds of construction work; the street department is using hydrants for filling roller tanks and many other uses; and the park department use hydrants for filling their barrels for the moth and bug mixtures; and so it goes. As a result we find it very hard to fix the responsibility for broken hydrants. Notwithstanding that we find a hydrant with a screw

* Superintendent of Water Works, Cambridge, Mass.

whose office it is to raise the valve bent in the form of an "S," the man who used it last swears that they tried to open it the right way. [Laughter.] When you are up against anything of that kind, the only solution of it is to make the screw and the rod so strong that they can't bend them. I think it was one of the early Boston superintendents, Mr. Jones, who said that the measure of the strength of a 6-inch gate spindle was not what was required to operate the gate, but what was required to stand the strength of two good burly men on the end of a long gate wrench.

Now, when it comes to that, gentlemen, your factors of safety have got to be modified considerably. I was interested in hearing Mr. Newcomb read of a hydrant bottom being pushed out. We recently had a case of that kind, yet the men swore that they were closing the hydrant in place of opening it; that the valve wasn't down; it was hardly clear how the bottom could come out, but nevertheless it did.

An amusing incident occurred in a damage suit for throwing water down a man's chimney from a broken hydrant and damaging the ceilings and carpets in his rooms and so forth. That occurred with one hydrant which you probably know very well, which has a composition bushing at the top of the hydrant in which the hexagonal rod fits, and the flange on this bushing keeps the bushing from coming out, being put in from below. That flange broke off, the rod went up through the top of the hydrant, and a 1½-inch stream went up into the air; the wind blew it over into this man's chimney, it went down his chimney, out of his fireplace, and ruined his ceilings and his carpets. Now the moral from that is, not to have fireplaces, I suppose. [Laughter.]

But seriously, I think that if all the combined talent was put at designing homely, ungainly things, they couldn't surpass the array of hydrants we have got at the present day. Boston has got an art commission that passes on every drinking fountain and lamp-post and so forth, but something is put in for a hydrant that is about as ungainly as anybody can conceive of.

Mr. McInnes. The old saying is, "Handsome is as handsome does."

The President. From Mr. Brooks's remarks it would seem as though there were room for one more commission in Boston.

We should like to hear from Mr. Sullivan on this matter of fire hydrants.

Mr. William F. Sullivan.* Mr. President, I doubt whether I can add anything of interest to what has been already said. I have listened with attention and profit to the scientific paper read by the gentleman from Holyoke.

Up in Nashua, where I come from, some citizens believed they knew considerable about hydrants. I refer to a few worthy people who don't take into consideration the location and elevation of the hydrants, size of mains and connections, or the normal pressure for the particular locality; who believe that ordinarily a fire hydrant makes an unsightly hitching-post, and would rather see it placed in front of their neighbor's premises; yet under the stress and excitement of a fire, without reckoning into account the local conditions or the length of hose, they are ready to criticise if the nozzle fails to deliver enough water instantaneously to extinguish a conflagration.

We have made a practical test of hydrants; compiled tables showing location, make, diameter of barrel, direction of opening, whether they were 2-, 3-, or 4-way hydrants, with or without steamer outlet; also obtained the static pressure with the normal city draft, the indicated pressure with stream or streams flowing, the difference or loss due to the different flows. From this compilation we were able, with the aid of "Fire Stream Tables," to obtain the discharge per minute, and thus find the actual value of our hydrants as fire-fighting machines, and enabling us also to compare the efficiency of hydrants in different localities.

We also inspected the hydrants for durability, readiness for use, ease of operation, etc.; also whether they wasted freely, whether the packing needed renewing, whether the spindles were bent or defective, or any other defect impaired their usefulness. The result of such examination showed about 3 per cent. of the spindles needed replacing, about 8 per cent. needed repacking, 2 per cent. of the wastes needed attention, two hydrants needed replacing, several outlet caps were rusted or frozen on, so that

* Superintendent Pennichuck Water Company, Nashua, N. H.

it required considerable time and hammering to loosen and remove them.

In addition we also noted the horizontal distance in feet reached by a hose stream, the flow being through 50 feet of best $2\frac{1}{2}$-inch rubber-lined hose and an underwriter's $1\frac{1}{8}$-inch nozzle or play pipe; this gave us some idea also of the efficiency of our hydrants.

The number of hydrants found inefficient, or I might say, dummy hydrants, — or, in other words, that were not capable of delivering at least one good fire stream, — was very small; I should say less than 1 per cent.

This year we have remodeled the distribution system to some extent; that is, increased the pipe diameters in a number of streets. The hydrant data having been obtained before changes were made, we again tested the hydrants in the vicinity of the improvements, which enabled us to determine how much we improved the fire service in any section.

The form of tabulation used in our inspection is as follows:

PENNICHUCK WATER WORKS, NASHUA, N. H.

HYDRANTS.

Date.
Street.
Location.
Make.
Size standpipe.
Opens.
No. of nozzles.
- 2-Way.
- 3-Way.
- 4-Way.
- Steamer.

Discharge $1\frac{1}{8}$-inch nozzle attached to 50 feet $2\frac{1}{2}$-inch hose (gage attached to hydrant).
- Pressures.
  - Static.
  - Stream flowing.
  - Difference.
- Gallons per minute.
- Horizontal stream (feet). No allowance for wind.

Discharge through one open hydrant butt (gage attached to hydrant).
- Pressures.
  - Static.

Stream flowing.
Difference.
Gallons per minute.
Discharge through open steamer butt (gage attached to hydrant).
Pressures.
Static.
Stream flowing.
Difference.
Gallons per minute.
Waste.
Packing.
Remarks.

As a record I believe that it is well to test and inspect hydrants periodically and find out their condition and value for the purposes for which they were installed.

We intend later to get the relative discharging capacities and the resultant loss of head of present-day commercial hydrants and their comparative costs.

The hydrant that is in most common use in our city is found suitable.

Our contract with the city of Nashua requires that all new hydrants shall be "Standard Six-Inch Hydrants." There seems to be a difference of opinion between water-works people, insurance underwriters, and fire departments as to what is a 6-inch hydrant. I should like to know whether a 6-inch hydrant means a 6-inch valve opening hydrant or a hydrant with a 6-inch barrel.

Mr. Stacy. Mr. President, it strikes me that this discussion has opened up another thought here. This Association has had various committees on different subjects to formulate standard rules for constructing different appliances for water works, and the importance of fire hydrants in water works seems to be so prominent that a committee might well be appointed on that subject, and if they put as much work into it as was put into the matter of standard specifications for cast-iron pipe by a committee, I think we would meet with some results.

The question has been asked, What is a 6-inch hydrant? We buy them. You may get a 6-inch post, you may get a 4-inch gate; you talk with somebody about it, and they say, "That 4-inch or 5-inch gate will give you as much water as a 6-inch post."

I hardly believe that myself; but a test might prove them right. I believe that an 8-inch pipe and an 8-inch gate and an 8-inch post will give me more water than a 5-inch gate and a 6-inch post and an 8-inch supply. I believe that where you want lots of water an 8-inch pipe is not any too much, and I want the gate pretty nearly the same size, too. However, that might be modified, perhaps, on investigation.

It seems to me that this is a function that this Association should take up; and I think we might evolve from that a Standard Hydrant of the New England Water Works Association that would be recognized as something better than what is put on the market to-day.

Now, if we have a standard hydrant,— as an underwriters' fire pump is standard,— then you would all be figuring on the same basis and the same construction, and we would know better where we stand when we come to buy hydrants, as to opening, quality of workmanship and capacity, gates, and everything else.

Mr. John H. Flynn.* I would like to ask if a hydrant with a 6-inch valve opened with pressure with a 7-inch barrel would be a 6-inch hydrant?

The President. My impression is that that is something that remains to be settled. [Laughter.] It depends, I think, on the manufacturer. It sometimes depends on the man who is ordering the hydrant. I think that is something that would be covered by such a committee as Mr. Stacy suggests.

It seems to me that Mr. Stacy's ideas on that subject are most excellent.

Mr. Stacy. I think a committee of five is large enough, and I should say it ought to be about that size. I haven't given that a great deal of thought, but, to bring it up before you, gentlemen, I move that a committee of five be appointed by the president to take up the subject of hydrant construction.

Mr. Flynn. Mr. President, I second that motion.

The President. It is moved and seconded that the president appoint a committee of five to consider and report on hydrant construction.

[The motion was put by the president, and declared to be a vote.]

* Assistant Superintendent, Boston Water Works.

Mr. Thomas. Mr. President, would it be a good idea to hear from some of the hydrant manufacturers? We have had one side of the case. I think Mr. Bates is here from the Rensselaer Manufacturing Company, Mr. Gould from the Ludlow Valve Manufacturing Company, and Mr. Hughes of the Chapman Valve Manufacturing Company. Wouldn't it be a good idea to hear from them on the hydrant matter?

The President. The Association will be pleased to hear from any of those gentlemen. I think Mr. Bates comes nearest to heading the alphabet.

Mr. F. S. Bates. Mr. President and gentlemen, the reading of this paper on fire hydrants brought up a most interesting subject, and the remarks made here to-day on the construction of fire hydrants are very interesting, not only to the active members of the New England Water Works Association, but also to the associate members who are actively engaged in the manufacture and sale of these fire hydrants to the various water departments.

I have found in my twenty-three years of experience, both from the manufacturing and the sales point of view, that all material consisting of either valves or fire hydrants should be purchased direct by the various water departments and not through contractors who are building the work, as they have a tendency to force the material or supply representatives to an extremely low figure before they will place their orders, and as a result the cities will suffer in the end by the cheapest and poorest material being introduced. The contractor looks at it from his point of view that the water board will stand behind him and will adopt whatever material he sees fit to purchase. As the specifications do not specify the design or the character of the hydrant, therefore the contractor accepts the lowest proposal possible to obtain on valves and hydrants and inserts these into his proposal, the result of which, in submitting his bid to the city, and using the lowest possible prices to obtain on material, would naturally make his total bid the cheapest but not the most beneficial to the city.

Therefore, if the water board does not take into careful consideration the durability of the material in the contractor's proposal, but simply awards the contract as a whole on account of its being the lowest proposal presented, and allows the contractor

to purchase his own valves and hydrants, the various city water departments are handicapped under such conditions and are, in a great many cases, forced to accept material which is detrimental to their department, while if they were purchasing direct they would go farther and investigate carefully the construction and details as well as the design of the valves and hydrants.

As Mr. Stacy said, there should be more and more careful work done in the machine shop; but what can a manufacturer do when he is forced to the lowest price limit and has the above questions to consider? I have also found from personal observation that frequently the workmanship and durability of either valves or hydrants has not been taken into consideration at all, but it is simply a question of price, which is a mistake. It is always for the best interest of water departments, and the communities which they represent, that they should recommend for adoption in their systems valves and hydrants that stand the highest in workmanship and durability. I also find that the majority of superintendents and engineers of private corporations give much more consideration to the details of construction of their various appliances before they are adopted than officials of our various cities usually do to the merits or demerits of the same. The corporation's point of view is, that they want an appliance that will stand, so that the repairs and cost of maintenance will be a nominal sum at the end of the fiscal year, but in many cities this important factor is not considered at all. It is a question of first cost only. "How much can they buy this or that article for?" and in nine out of ten cases the price of a good article seems too high, and the lowest price, and consequently the cheapest and poorest valve and hydrant, are taken, although, I assure you, that the prices submitted to-day by the reputable concerns making valves and hydrants are exceptionally low ones, considering the price of raw material and labor.

In regard to screwing the $2\frac{1}{2}$-inch nozzle into the standpipe: it is an excellent idea and should be adopted by all water works. In well-regulated shops there is no difference in the cost of construction between a nozzle that is leaded in and one that is screwed in, but the one that is screwed in will render the best service and be more easily replaced in case of accident. Consider the con-

struction of the nozzles in the fire hydrants in use at Coney Island, where the nozzles are leaded in and were melted out by the heat of the fire. I had the honor of receiving this order, and before proceeding with the construction of hydrants we recommended to the department that they should be screwed in, but it was considered it might be a detriment to the hydrant to have them screwed in. I showed them the method of screwing nozzles into hydrants, and that by putting a thread in the standpipe reverse to that on the hose end of the nozzles it would keep such nozzle in place; and by putting a set screw on the outside of the nozzle through the cast-iron part it would also prevent this nozzle from unscrewing out of the hydrant during the taking off or putting on of the hose connection. Unfortunately, we find also that in a large number of the cities and towns of New England the hydrants are furnished with the nozzles leaded in, but if superintendents and engineers, on issuing their orders, would specify or request that their hydrant nozzles be screwed in we would only be too glad to furnish the same.

In relation to the standardization of hose threads and operating nut, we have recommended and furnished the same to new water works plants and have also recommended same to those who seemed desirous of adopting some other city standard. A large number of cities are recommending this change, so that in due course of time a large percentage of our water departments will have this new style of thread and operating nut, for which, of course, this water works association deserves some of the credit.

I do not know as I could add anything more to this important subject, but the points that I have demonstrated to you I consider are valuable ones and should be taken into careful consideration by the various superintendents here. I speak only as one of the associate members, as we are all here for the purpose of trying to bring before the active members the latest improved water-works devices and those that are best designed and constructed and suited for their water-works systems.

It is a great and difficult study for us to please all, but we are always willing to take advice and suggestions that are given. After we have ferreted out and proved suggestions given us by

you gentlemen, and find they will be of benefit to our hydrants and valves, we are willing to accept and manufacture the same.

I thank you, gentlemen, for your attention, and also for the invitation extended to me to make a few remarks on this subject.

The President. We would like to hear from Mr. Hughes, of the Chapman Valve Manufacturing Company.

Mr. Hughes. I don't know that I can add anything to what Mr. Bates has said, Mr. President. If this matter was taken up and thoroughly thrashed out, I think you would get a better distribution of metal in a great many cases, a different kind of metal, more suitable for the purposes than is used sometimes.

As regards Mr. Bates's remarks on screwed nozzles, I think that can be thrashed out in debate; I don't quite agree with him; I can see some trouble in water departments through having screwed nozzles.

The President. We should like to hear from Mr. Gould. I don't get my eye on him, but I think he is here somewhere.

[Mr. Gould was not present at this time.]

The President. My impression is that a committee of this Association — possibly two years ago — recommended that the hydrant have cast upon its top an arrow showing the direction in which it should be opened. As we have some hydrant men here I should like to inquire if that recommendation has ever been carried out by the hydrant builders.

Mr. Hughes. I saw you looking this way, Mr. President, and I will say that the hydrants that I am familiar with have the arrow.

Mr. Flynn. I don't know that it would make much difference whether there was an arrow or not. [Laughter.]

Mr. F. L. Fuller.* Mr. President, there is one matter I think might be brought up in connection with this paper, and that is the care of hydrants. I think in many towns and cities hydrants are very much neglected. I had occasion during the past summer to examine about one hundred and twenty hydrants in a certain town, and I was surprised to find in what poor condition they were. They were of various manufactures and apparently very little attention had been given to them for a long time. In many of them the

* Civil Engineer, Boston, Mass.

packing had largely disappeared, and almost all of them had been screwed down to such a degree that they could not be started with an ordinary wrench. I found that those who had previously used them (for the most part men employed in flushing sewers) had opened and closed them with a very long wrench. Wrenches more than three feet long were sometimes used.

It seems to me that a hydrant, of all things, is an instrument or appliance which ought to be kept in the very best order. Yet I venture to say that in a great many towns the hydrants are, to a considerable extent, in poor working condition. They open hard; there are no washers, perhaps, in the nozzle caps, so that if only one line of hose is attached there is a large stream of water flowing from the other nozzle. I found this to be the case especially where there were steamer nozzles; there was generally no washer, no packing in these nozzle caps, and a large stream of water escaped from the hydrant because the cap did not make a tight joint with the hydrant.

A hydrant ought to open and close easily; it ought to be closed only sufficiently to open the drip and properly close the inlet valve, and it ought to be so oiled or greased that it will turn easily. A great many of the hydrants referred to squeaked while being opened or shut, which seemed to indicate that nothing had been done in the way of lubrication for a long time. Oftentimes a stream of water came out between the hydrant and the hydrant head. To say nothing of the water thus wasted, which should be used for extinguishing the fire, it is, to say the least, unpleasant for firemen to be obliged to stand by and manipulate a hydrant, from which the water is spurting in all directions. In cold, freezing weather this duty becomes doubly disagreeable. It is inexcusable that hydrants should be found in such a condition. I believe the water department of a town or city should have entire charge of all hydrants at all times, except in case of fire or during fire drills or practice, and the water department should be held responsible for their condition.

Watering carts should be filled from standpipes properly located, and not from hydrants.

In flushing sewers with hose from a hydrant, a large and generally unknown quantity of water is used. The sudden draft of

water is liable, in some systems, to cause consumers annoyance by furnishing them with roily water, although it may be argued that in such a case the blowing off of the hydrants is an advantage, as it tends to keep the pipes clean. When the supply is of good quality, it is seldom necessary to blow off the hydrants, except, perhaps, at dead ends, where the consumption may be small.

A method of flushing sewers which obviates the necessity of using hydrants, and is generally satisfactory, is to provide the manholes at summits with a simple iron flushing gate or plug by which the outlet can be temporarily closed. Water is admitted to the manhole by means of a faucet or valve in the manhole attached to a service pipe from the nearest main. When the water has reached a suitable height in the manhole, the outlet is suddenly opened by raising the gate or withdrawing the plug by means of a chain attached thereto. This allows the outflow of a considerable quantity of water, causing a thorough flush. This water can, of course, be metered, if desired, as it enters the manhole.

The proper care of hydrants is certainly an important matter.

Mr. John C. Chase.* Mr. President, I would like to follow up the line of thought suggested by Mr. Fuller. The fire hydrant is a fixture that has a specific function in a water works plant. It is ordinarily used infrequently, but when its service is wanted at fires there is nothing that will take its place. Now I maintain that it should be kept religiously for the purpose for which it was designed; that is, as a part of the fire-fighting apparatus, and its non-use for every other purpose should be firmly insisted upon except under the supervision of the water department. I have always made that a point in the management of the works with which I have been connected, and with giving them a regular and proper amount of attention to see that they are in good working order, and watching out to see that they are not maliciously interfered with, they have always been ready to respond when called upon.

Another thought that has been suggested by Mr. Bates is in relation to the cheapening of hydrant and valve construction. I

* Civil Engineer, Derry, N. H.

do not think the manufacturers are so much to blame for any inferior quality of their product as the purchasers, who are calling for the lowest possible price for the article they want. Now a little illustration of contractor's methods, or, perhaps I should say, the method of one that came under my own observation: Some thirty-five years ago a New Hampshire city built a system of water works, and the whole pipe system with hydrants and valves was let, in one contract, to a prominent New England contractor. It was specified that he should furnish certain well-known hydrants and valves made by a reliable manufacturing company, which were to be first-class in every particular. When the works were about half completed water was furnished for a limited use and the hydrants were put into service. It was noticed that there was a slack motion in the valve rod of some of them and when a hydrant was being used on the lower level, where the pressure was some 85 pounds to the square inch, the valve seated itself suddenly when it was nearly closed and the resulting water hammer caused the hydrant and supply pipe to part company, with a disastrous effect upon the street in the immediate vicinity.

The maker of the hydrants was notified to appear and make good the defects. The mechanic who was sent up incidentally remarked that we "could not expect anything better from second-class work." "Second-class work! why, we called for the best." "Well, I do not know what you called for, but this is not our best work; you do not find our name upon it, do you?" And I had to admit that he was right. Work had been sent out that the makers did not care to have their name upon, but they made the deficiencies good, however. When the works were tested upon completion, some two years later, with a large number of fire streams playing, one of the hydrants suddenly stopped work and the water began to boil up on the outside. It turned out that in opening it an excessive strain had been put on the valve rod, which struck the post at the bottom and broke a hole through the shell. Later inspection showed that several unused hydrants were lacking in proper thickness at the base. Here was a case where a concern with a reputation for first-class work had, in order to meet competition and the demands of the contractor,

sent out what was not up to the required standard, with a consequent loss of money and reputation.

MR. THOMAS. Mr. President, isn't it a fact that there are not hydrants enough used in cities, and that they are not distributed numerously enough around, especially in the central parts of the city?

I think I can safely say, without even speaking in the interests of the hydrant manufacturers, that there are too few hydrants used; they ought to be nearer together; then if one of them is out of order, you have another close by that you can use. Where the hydrants are placed 1 000 feet apart there ought to be three instead of one; then if one was out of order, you would have two more to fall back upon. I don't believe in a few big hydrants so much as I do in a number of smaller hydrants. Have them closer together; do away with the friction of long lines of hose.

I believe that the hydrant manufacturers, if they are given time and sufficient notice, will furnish all the hydrants required, and furnish them just as the water-works people want them. The trouble is not with the hydrant manufacturers altogether. All the superintendents have got to do is to take their JOURNAL and look at the advertising pages; they will find there the names of hydrant manufacturers who make hydrants first class in workmanship and of high-grade material.

I should urge upon all the superintendents not to be sparing in putting in hydrants. But don't put them in front of every man's house that you have a grievance against. [Laughter.]

MR. FLYNN. I should like to say to Mr. Thomas that I don't see any use of putting in too many hydrants. If a hydrant gets out of order I don't know what good it is going to do to have one next door to it, because the engine can't get away from it, but has got to stay right there until the water works people come along and unhitch it. [Laughter.]

MR. THOMAS. There isn't any fireman that I ever knew of that would stand in front of a stream.

MR. HUGH MCLEAN.* Something has been said about the care of hydrants. I would like to cite you a case where I know hydrants are taken care of, and that is the city of Holyoke. I believe a

* Chairman Water Board, Holyoke, Mass.

city of 20 000, 30 000, 50 000, or 100 000 population or over ought to have a hydrant man in its water department, a man who responds to all fire alarms, and after the fire is over sees that the hydrants are closed down tight as they ought to be, and goes round and examines them and sees that they are all right and properly drained off; a man whose duty it would be to go around to the hydrants twice a year and flush them off, and see that they are thoroughly in order.

We have such a man in our city, and that is his duty — taking care of hydrants. We have a fire alarm gong in his bedroom and he responds to all fire alarms and takes his hydrant kit along with him; if there is anything wrong about the hydrant he telephones down to the shop immediately and a couple of men come right along. No hydrant is opened without his permission; that is, unless for fire purposes. Through the day, if they are needed for sewer flushing or any other purposes, they must be opened by him and closed by him; so that, if anything is wrong about the hydrant, should it freeze up or be out of order, then the department is responsible through him.

I believe that there is no better system of taking care of hydrants than in having a man in every department whose duty it will be to respond to fire alarms and take care of the hydrants when the fire is over.

Mr. Stacy. Mr. President, from the remarks of brother Thomas I know how he feels in his position, that we are criticising the hydrant makers. I know he feels pretty tender on that point, and well he should, because I think that his success as our advertising agent has depended a good deal on his tender heart. [Laughter.] Really, without any joking, I don't take this to be a criticism of the manufacturers of hydrants, because I think they are giving us just what we are asking for, and as good a thing as they can for the price we are willing to pay.

And I believe another thing: After you get a good hydrant or a good watch, in order to keep it good you have got to take care of it. Up in our little city of 15 000 inhabitants nobody uses a hydrant without permission, except in case of fire. When the highway department or the sewer department want to use a hydrant I furnish a man to operate it. I have held to that.

Sometimes it has been uphill work and I have had to make myself disliked in some quarters, but I have carried that point because I believed it was right. I would say that the relations between the highway and water department, with one or two exceptions, have always been pleasant.

We have a man who is responsible for the care of hydrants and responds to fires. Unfortunately, I am the fellow. [Laughter.] I have a gong in my house, and my wife wishes it was in somebody's else house. [Laughter.] Some time we may be large enough to have a man whose only business will be to take care of the hydrants.

The way I do with the street department is this: In the spring I give the man who runs the steam roller a numbered hydrant wrench; and he reports what hydrants he uses and he returns the wrench in the fall.

If any department desires the use of a hydrant, I try to accommodate them in every possible way, but I insist on keeping the hydrants in my control as long as they hold me responsible for them.

We shall have better hydrants when we demand them and when we are willing to pay for them, and when we get them they will be good hydrants just as long as we are willing to take care of them.

The President. Mr. Brooks, don't you admire Mr. Stacy's success in keeping other people away from the hydrant?

Mr. Brooks. I wish he would come down our way.

Mr. Stacy. Perhaps under other conditions that would be impossible. It isn't one man's smartness, it is the sentiment that happens to grow up and the class of men that surround you and have the power to back you up. I know places where it is impossible for the superintendent to do that, because there are other influences that come in and prevent him.

As far as the number of hydrants is concerned, I think that's another good point. I believe in plenty of hydrants, and I have tried to practice what I preach in that matter. In all of our factory places I can put on 12 to 16 streams, and the longest line of hose will not be over 300 feet. Working at a fire the lines would be somewhat longer.

So I say that the hydrant makers are all right, brother Thomas, and they make good hydrants, and will make better ones if we demand them.

Mr. George Cassell.* This paper that has been read here this afternoon deals, as I understand it, largely with the friction loss in the different fire hydrants manufactured. Now it seems to me that that is a matter that is purely up to the manufacturers of hydrants, and with this table showing the results that it does, it seems to me that it ought to be an incentive to the representatives of the different manufacturers who are assembled here this afternoon to get a hustle on [laughter], because there is no doubt in my mind but what in the future I will make an attempt to secure the hydrant with the least friction loss.

In relation to the condition of fire hydrants, I don't think the trouble is confined wholly to the hydrant. I believe, as has been stated here this afternoon, that it is due to the manipulation of the fire hydrants by people who do not understand the mechanism of them. In my city that is the only trouble I have, and I am sorry to say that I am unable to stop it, simply because, as my friend Stacy here has said, of the interference of others who are a little higher up.

I had a case of that kind where I issued an order to the superintendent of streets and city engineer that he should not manipulate any fire hydrants for any purpose without notifying the department, and that the department would furnish men to manipulate them for him. Well, he didn't seem to like that very well, so he went up to the mayor (not the present mayor, but a mayor three or four terms back; yes, six or seven, because the present mayor as is, has been mayor for the last five years), and the mayor said to him, "Don't you pay any attention to that; you use the fire hydrants all you want to." Well, that was all right enough, and didn't bother me for a cent. I met the mayor on the street a few evenings afterwards, and it happened to be just before election for the executive of the city. He said to me, "What is all this row about the fire hydrants?" I said, "I didn't know there was any row about the fire hydrants, I didn't hear any." He said, "The city engineer has told me you

* Superintendent of Water Works, Chelsea, Mass.

notified him not to use them any more." I said, "Yes, I did." He said, "I told him to use them all he wants to." I said, "Very well, the responsibility for their condition is up to you now, not on the water department." He said, "What do you mean by that?" I said, "Come round the corner and I will show you." It happened to be in the winter time and they had been laying vitrified brick and had been using the water from hydrants for making the concrete base, and I had just come from an examination of two hydrants which were frozen to the nozzle. I showed them to him and said, "That is what I mean." He said, "You find out who did that." I said, "No, sir; you find out." [Laughter.] I said, "I am going to have them put in condition, but if there is any finding out to do you will do it and I won't." He said I was trying to make all the trouble I could just before election.

Now, gentlemen, the fire hydrants (with the exception of the friction loss that has been talked about here), so far as I have been able to learn in my experience of a great many years, are all right if let alone or manipulated by men who understand the mechanism of them. And until we can get those in authority to back us up in not allowing the use of those hydrants by people for street watering purposes, or any other purpose, then just so long will we have that trouble.

Now, the mayor that I have just been telling you about was in the insurance business, and still he told that man to use all the hydrants just as much as he wanted to! So you can see that the fault is not with the hydrant; it is not with the superintendent or whatever official is in charge of them, but it is with those who interfere with the business of the superintendent. And there is no trouble that comes so quickly or is so great as the trouble that comes from somebody minding somebody's else business.

We are troubled in our city with the drips, as Mr. Stacy mentioned, but we take all the precaution within our power to prevent our hydrants from being frozen in the winter time, and it requires some supervision. There are numerous cases where hydrants will freeze under certain conditions. For instance, our hydrants are set at 5-foot bottom. Now there are different kinds of soil, and we find that in severe winters like the past the frost will go down

in gravelly soil and we have got to examine and test those hydrants almost every twenty-four hours, especially where the railroad tracks cross above the pipes leading to them.

In regard to the hydrants with the drips that are liable to fill up with surface water, we have that to contend with. And in such cases we plug the drip port and keep the hydrants pumped out, and make an examination in thoroughly cold weather almost every day, sometimes twice, of all hydrants. But it pays to do it. And we have never been caught yet, to my knowledge, with a frozen hydrant when it was needed. Perhaps it was because it wasn't needed when it was frozen. [Laughter.]

We don't want to blame the hydrants, because nine times out of ten the hydrants are not to blame, and I believe that (with the possible exception of what has been brought forward in this paper on friction loss) there is almost no fault to be found, although there is always room for improvement, and the manufacturer who gets on the ground first is going to be the winner.

STREAM FLOW DATA FROM A WATER-POWER STANDPOINT.

BY CHARLES E. CHANDLER, CIVIL ENGINEER, NORWICH, CONN.

[*Read November 13, 1907.*]

Long-term data regarding stream flow are not abundant. Records of the Croton flow have been kept continuously longer than on any other stream, so far as the writer knows. I am not aware that the Croton thirty-eight-year record is anywhere in print in one table, as shown in Table No. 1. There is a gap in the data in the water supply and irrigation papers, which it was found somewhat difficult to fill.

Stream-flow data arranged by months chronologically do not average fairly, and the next table has the same data with the months arranged in order of magnitude. This table (No. 2) is much more useful for water-power purposes than the first one.

A still further improvement may be made, so far as the lower flows are concerned, by arranging all the months in the whole term in order of magnitude as in Table No. 3, instead of arranging the months in each year in order of magnitude.

Table No. 4 compares the results obtained by the three methods shown in preceding tables, and shows how much nearer to the truth is the last method.

The arrangement of Table No. 3 is absolutely correct in its theory. Whenever the flow of a stream is greater than can be used by the water wheels installed, a part of the flow is unavailable. Water-wheel developments, as a rule, leave much water to run over the dams unused. Arranging all the months of the whole term in order of magnitude, instead of each year separately, eliminates all that part of all flows that must run over the dam instead of through the wheels at any given development.

The information to be obtained, working on this principle, is given in greater detail, and in days as well as months, in Table No. 5. Column A gives all the monthly flows that occurred during the thirty-eight years in order of magnitude, and in

column B the number of months in which each flow occurred during the whole period. Column C masses these months and hence gives the number of months in which a given flow, and flows less than the given flow, occurred. Multiplying the massed months by 0.8 gives in column F the annual average massed days. (30.4 days in the average month; record covers 38 years; 30.4 ÷ 38 = 0.8.)

By multiplying the given flows by the number of months in which they occurred (column D) and massing the products (column E) and dividing by the massed months, we have in column G the average flow of the massed months. Column H gives the average available flow at all developments in column A.

The Croton flow was used for this illustration, not only because of the length of the period of observation, but because its watershed is larger than that of other water supplies, regarding the flows of which long term records exist, making the data more useful for power purposes.

Of course, these or any other data that are computed monthly do not show the real extreme minimum flow, and at moderate developments considerable unavailable stream flow is included as available.

The daily records of the Connecticut at Holyoke furnish very valuable stream flow data for power purposes.

The idea of arranging in order of magnitude the different flows of the whole term covered by the data, instead of treating each year separately, occurred to the writer several years ago when reporting on several large waters powers for a power company.

The Holyoke data kindly given him by Mr. A. F. Sickman were in form of second feet for the whole of the drainage area for each day of each year in order of magnitude. These have been reduced to second feet per square mile and arranged as shown in Table No. 6.

TABLE No. 1.

CROTON RIVER. DRAINAGE AREA, 338.8 SQUARE MILES. MONTHLY DATA. FLOW IN CUBIC FEET PER SECOND PER SQUARE MILE ARRANGED CHRONOLOGICALLY.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.	Average.
1868	1.52	.68	3.39	3.04	4.64	2.64	.85	1.59	.44	2.29	2.75	1.21	25.04	2.45
1869	1.74	1.69	4.32	2.71	2.21	1.05	.46	.26	.16	2.07	1.66	2.49	20.82	1.74
1870	3.07	3.70	2.74	3.59	1.38	.64	.39	.39	.28	.33	.49	.46	17.46	1.44
1871	.45	1.90	2.71	1.57	1.56	1.12	.53	.65	.48	1.54	2.98	1.74	17.23	1.43
1872	1.58	.99	1.33	2.47	.96	.94	.46	1.26	.95	.83	2.12	1.08	14.97	1.24
1873	3.33	1.42	3.14	5.79	1.65	.42	.37	.55	.41	1.09	1.34	2.32	21.83	1.84
1874	8.19	2.37	2.31	2.89	2.45	.70	1.08	.67	.45	.59	.54	.70	22.94	1.83
1875	.46	3.55	2.49	4.51	1.39	.44	.43	4.22	.67	.63	1.74	1.36	21.89	1.81
1876	1.10	3.07	5.52	5.03	1.53	.53	.41	.38	.30	.29	.55	.36	19.07	1.58
1877	.61	1.25	5.37	2.34	.67	.47	.38	.37	.27	.79	3.45	1.49	17.46	1.46
1878	2.24	3.31	3.00	1.31	1.17	1.15	.55	.49	1.87	.69	1.64	6.06	23.48	1.95
1879	1.07	2.36	3.31	4.08	1.45	.69	.55	1.08	.87	.48	.62	1.46	18.02	1.49
1880	2.09	2.41	2.26	1.63	.67	.41	.41	.38	.39	.38	.44	.41	11.88	.98
1881	.56	3.91	4.69	1.47	1.04	1.34	.43	.41	.41	.41	.36	1.36	16.39	1.35
1882	1.81	3.79	4.03	1.11	1.78	1.33	.52	.41	2.65	1.72	.74	.98	20.87	1.73
1883	.86	2.98	2.25	2.17	1.03	.53	.41	.41	.39	.50	.53	.47	12.53	1.03
1884	1.54	4.77	3.96	2.40	1.46	.52	.63	.92	.57	.42	.78	3.04	21.01	1.72
1885	3.38	2.18	1.57	2.09	1.21	.46	.39	.44	.35	.42	1.67	1.62	15.78	1.31
1886	2.75	4.22	1.94	3.81	1.65	.63	.46	.43	.39	.39	.69	.93	18.29	1.50
1887	2.24	4.42	2.94	2.69	1.01	.94	2.09	2.81	.72	.81	.77	1.92	23.36	1.93
1888	3.24	4.06	3.79	4.13	2.12	1.11	.43	.85	2.67	2.00	2.54	4.25	31.19	2.59
1889	3.55	2.04	1.62	2.08	1.34	1.45	1.23	3.29	1.85	1.49	4.41	3.70	28.05	2.32
1890	1.78	2.82	3.86	2.68	2.09	1.35	.66	.48	1.71	2.68	1.69	1.33	23.13	1.91

1891	5.62	5.19	3.45	2.01	.74	.64	.65	.67	.66	.64	.56	.98	21.81	1.80
1892	2.97	1.23	1.49	.97	1.15	.98	.73	.71	.78	.68	1.24	1.30	14.23	1.19
1893	1.49	2.55	5.09	2.83	4.79	.84	.74	.86	.75	.98	1.25	2.60	24.77	2.06
1894	1.31	1.83	4.03	1.93	1.47	1.25	.76	.74	.77	.72	1.95	1.77	18.53	1.54
1895	2.35	.91	2.68	3.15	1.04	.75	.75	.78	.82	.75	.72	.75	15.45	1.29
1896	1.03	2.07	4.62	2.34	.47	.92	.85	.92	.88	.89	1.29	.91	17.19	1.47
1897	1.10	1.90	2.44	2.01	2.26	1.19	2.13	2.44	1.01	.88	.91	1.79	20.06	1.68
1898	2.98	4.34	2.62	1.76	3.89	1.55	.95	1.77	1.03	1.15	1.67	2.67	26.38	2.19
1899	3.17	2.57	6.06	3.30	.99	1.03	1.01	1.05	1.02	1.04	1.04	1.03	23.31	1.94
1900	1.53	6.26	4.77	1.73	2.19	.63	.39	.10	.27	.48	1.18	1.67	21.20	1.74
1901	1.06	.46	4.47	6.78	3.70	1.44	1.23	3.75	1.93	2.32	1.11	4.08	32.33	2.71
1902	3.28	2.82	8.55	2.88	1.56	.74	.64	.50	.62	2.10	1.27	4.79	29.75	2.49
1903	3.15	3.56	5.24	3.02	.54	2.95	1.36	1.32	1.62	4.35	1.53	2.36	31.00	2.58
1904	2.00	2.62	4.73	2.85	1.42	1.04	.74	1.06	2.28	1.38	1.23	.95	22.30	1.86
1905	3.80	1.13	3.76	3.11	.80	1.04	.33	.45	1.17	.64	.54	1.03	17.80	1.50
Total...	86.00	103.33	136.54	106.26	63.47	37.85	27.38	39.86	34.86	41.84	51.99	69.42	798.80	
Average ..	2.26	2.72	3.59	2.80	1.67	1.00	.72	1.05	.92	1.10	1.37	1.83	1.75	

TABLE No. 2.

CROTON RIVER. DRAINAGE AREA, 338.8 SQUARE MILES. MONTHLY DATA. FLOW IN CUBIC FEET PER SECOND PER SQUARE MILE ARRANGED IN ORDER OF MAGNITUDE IN EACH YEAR.

	1	2	3	4	5	6	7	8	9	10	11	12	Total.	Av.
1868.....	.44	.68	.85	1.21	1.52	1.59	2.29	2.64	2.75	3.04	3.39	4.64	25.04	2.45
1869.....	.16	.26	.46	1.05	1.66	1.69	1.74	2.07	2.21	2.49	2.71	4.32	20.82	1.74
1870.....	.28	.33	.39	.39	.46	.49	.64	1.38	2.74	3.07	3.59	3.70	17.46	1.44
1871.....	.45	.48	.53	.65	1.12	1.54	1.56	1.57	1.74	1.90	2.71	2.98	17.23	1.43
1872.....	.46	.83	.94	.95	.96	.99	1.08	1.26	1.33	1.58	2.12	2.47	14.97	1.24
1873.....	.37	.41	.42	.55	1.09	1.34	1.42	1.65	2.32	3.14	3.33	5.79	21.83	1.84
1874.....	.45	.54	.59	.67	.70	.70	1.08	2.31	2.37	2.45	2.89	8.19	22.94	1.83
1875.....	.43	.44	.46	.63	.67	1.36	1.39	1.74	2.49	3.55	4.22	4.51	21.89	1.81
1876.....	.29	.30	.36	.38	.41	.53	.55	1.10	1.53	3.07	5.03	5 52	19.07	1.58
1877.....	.27	.37	.38	.47	.61	.67	.79	1.25	1.49	2.34	3.45	5.37	17.46	1.46
1878.....	.49	.55	.69	1.15	1.17	1.31	1.64	1.87	2.24	3.00	3.31	6.06	23.48	1.95
1879.....	.48	.55	.62	.69	.87	1.07	1.08	1.45	1.46	2.36	3.31	4.08	18.02	1.49
1880.....	.38	.38	.39	.41	.41	.41	.44	.67	1.63	2.09	2.26	2.41	11.88	.98
1881.....	.36	.41	.41	.41	.43	.56	1.04	1.34	1.36	1.47	3.91	4.69	16.39	1.35
1882.....	.41	.52	.74	.98	1.11	1.33	1.72	1.78	1.81	2.65	3.79	4.03	20.87	1.73
1883.....	.39	.41	.41	.47	.50	.53	.53	.86	1.03	2.17	2.25	2.98	12.53	1.03
1884.....	.42	.52	.57	.63	.78	.92	1.46	1.54	2.40	3.04	3.96	4.77	21.01	1.72
1885.....	.35	.39	.42	.44	.46	1.21	1.57	1.62	1.67	2.09	2.18	3.38	15.78	1.31
1886.....	.39	.39	.43	.46	.63	.69	.93	1.65	1.94	2.75	3.81	4.22	18.29	1.50
1887.....	.72	.77	.81	.94	1.01	1.92	2.09	2.24	2.69	2.81	2.94	4.42	23.36	1.93
1888.....	.43	.85	1.11	2.00	2.12	2.54	2.67	3.24	3.79	4.06	4.13	4.25	31.19	2.59
1889.....	1.23	1.34	1.45	1.49	1.62	1.85	2.04	2.08	3.29	3.55	3.70	4.41	28.05	2.32
1890.....	.48	.66	1.33	1.35	1.69	1.71	1.78	2.09	2.68	2.68	2.82	3.86	23.13	1.91

1891	.56	.64	.64	.65	.66	.67	.74	.98	2.01	3.45	5.19	5.62	21.81	1.80
1892	.68	.71	.73	.78	.97	.98	1.15	1.23	1.24	1.30	1.49	2.97	14.23	1.19
1893	.74	.75	.84	.86	.98	1.25	1.49	2.55	2.60	2.83	4.79	5.09	24.77	2.06
1894	.72	.74	.76	.77	1.25	1.31	1.47	1.77	1.83	1.93	1.95	4.03	18.53	1.54
1895	.72	.75	.75	.75	.75	.78	.82	.91	1.04	2.35	2.68	3.15	15.45	1.29
1896	.47	.85	.88	.89	.91	.92	.92	1.03	1.29	2.07	2.34	4.62	17.19	1.47
1897	.88	.91	1.01	1.10	1.19	1.79	1.90	2.01	2.13	2.26	2.44	2.44	20.06	1.68
1898	.95	1.03	1.15	1.55	1.67	1.76	1.77	2.62	2.67	2.98	3.89	4.34	26.38	2.19
1899	.99	1.01	1.02	1.03	1.03	1.04	1.04	1.05	2.57	3.17	3.30	6.06	23.31	1.94
1900	.10	.27	.39	.48	.63	1.18	1.53	1.67	1.73	2.19	4.77	6.26	21.20	1.74
1901	.46	1.06	1.11	1.23	1.44	1.93	2.32	3.70	3.75	4.08	4.47	6.78	32.33	2.71
1902	.50	.62	.64	.74	1.27	1.56	2.10	2.82	2.88	3.28	4.79	8.55	29.75	2.49
1903	.54	1.32	1.36	1.53	1.62	2.36	2.95	3.02	3.15	3.56	4.35	5.24	31.00	2.58
1904	.74	.95	1.04	1.06	1.23	1.38	1.42	2.00	2.28	2.62	2.85	4.73	22.30	1.86
1905	.33	.45	.54	.64	.80	1.03	1.04	1.13	1.17	3.11	3.76	3.80	17.80	1.50
Total.....	19.51	24.44	27.62	32.43	38.40	46.89	54.19	67.89	81.30	102.53	128.87	174.73	798.80	
Average ..	.51	.64	.73	.85	1.01	1.23	1.43	1.79	2.14	2.70	3.39	4.60	1.75	

TABLE No. 3.

Croton River. 1868 to 1905 Inclusive.
Drainage Area 338.8 Square Miles. Monthly Data.

Flow in cubic feet per second per square mile arranged in order of magnitude for whole term instead of each year separately.

1	2	3	4	5	6	7	8	9	10	11	12
.10	.42	.54	.70	.91	1.06	1.33	1.59	2.00	2.44	3.02	4.03
.16	.42	.54	.71	.91	1.06	1.33	1.62	2.01	2.45	3.04	4.03
.26	.42	.54	.72	.91	1.07	1.33	1.62	2.01	2.47	3.04	4.06
.27	.43	.55	.72	.92	1.08	1.34	1.62	2.04	2.49	3.07	4.08
.27	.43	.55	.72	.92	1.08	1.34	1.63	2.07	2.49	3.07	4.08
.28	.43	.55	.73	.92	1.08	1.34	1.64	2.07	2.54	3.11	4.13
.29	.43	.55	.74	.93	1.09	1.35	1.65	2.08	2.55	3.14	4.22
.30	.44	.56	.74	.94	1.10	1.36	1.65	2.09	2.57	3.15	4.22
.33	.44	.56	.74	.94	1.10	1.36	1.66	2.09	2.60	3.15	4.25
.33	.44	.57	.74	.95	1.11	1.36	1.67	2.09	2.62	3.17	4.32
.35	.44	.59	.74	.95	1.11	1.38	1.67	2.09	2.62	3.24	4.34
.36	.45	.61	.74	.95	1.11	1.38	1.67	2.10	2.64	3.28	4.35
.36	.45	.62	.75	.96	1.12	1.39	1.69	2.12	2.65	3.29	4.41
.37	.45	.62	.75	.97	1.13	1.42	1.69	2.12	2.67	3.30	4.42
.37	.46	.63	.75	.98	1.15	1.42	1.71	2.13	2.67	3.31	4.47
.38	.46	.63	.75	.98	1.15	1.44	1.72	2.17	2.68	3.31	4.51
.38	.46	.63	.75	.98	1.15	1.45	1.73	2.18	2.68	3.33	4.62
.38	.46	.63	.76	.98	1.17	1.45	1.74	2.19	2.68	3.38	4.64
.38	.46	.64	.77	.99	1.17	1.46	1.74	2.21	2.69	3.39	4.69
.39	.46	.64	.77	.99	1.18	1.46	1.74	2.24	2.71	3.45	4.73
.39	.46	.64	.78	1.01	1.19	1.47	1.76	2.24	2.71	3.45	4.77
.39	.47	.64	.78	1.01	1.21	1.47	1.77	2.25	2.74	3.55	4.77
.39	.47	.64	.78	1.01	1.21	1.49	1.77	2.26	2.75	3.55	4.79
.39	.47	.65	.79	1.02	1.23	1.49	1.78	2.26	2.75	3.56	4.79
.39	.48	.65	.80	1.03	1.23	1.49	1.78	2.28	2.81	3.59	5.03
.39	.48	.66	.81	1.03	1.23	1.49	1.79	2.29	2.82	3.70	5.09
.39	.48	.66	.82	1.03	1.23	1.52	1.81	2.31	2.82	3.70	5.19
.41	.48	.67	.83	1.03	1.24	1.53	1.83	2.32	2.83	3.70	5.24
.41	.49	.67	.84	1.03	1.25	1.53	1.85	2.32	2.85	3.75	5.37
.41	.49	.67	.85	1.03	1.25	1.53	1.87	2.34	2.88	3.76	5.52
.41	.50	.67	.85	1.04	1.25	1.54	1.90	2.34	2.89	3.79	5.62
.41	.50	.67	.85	1.04	1.26	1.54	1.90	2.35	2.94	3.79	5.79
.41	.52	.68	.86	1.04	1.27	1.55	1.92	2.36	2.95	3.80	6.06
.41	.52	.68	.86	1.04	1.29	1.56	1.93	2.36	2.97	3.81	6.06
.41	.53	.69	.87	1.04	1.30	1.56	1.93	2.37	2.98	3.86	6.26
.41	.53	.69	.88	1.04	1.31	1.57	1.94	2.40	2.98	3.89	6.78
.41	.53	.69	.88	1.05	1.31	1.57	1.95	2.41	2.98	3.91	8.19
.41	.53	.70	.89	1.05	1.32	1.58	2.00	2.44	3.00	3.96	8.55
13.55	17.78	23.77	29.81	37.55	44.85	55.17	66.93	84.00	103.56	131.36	190.47
0.36	0.46	0.62	0.78	0.99	1.18	1.45	1.76	2.21	2.73	3.46	5.01

TABLE No. 4.

CROTON RIVER. DRAINAGE AREA 338.8 SQUARE MILES.
MONTHLY DATA. 1868 TO 1905 INCLUSIVE.

Comparison of Available Flow Averaged by Three Different Methods.

A. Average flow in second feet per square mile.
B. Massed flow.
C. Average flow of months equal to or less than development "A."
D. Average available flow for the year with development "A."

	Months.	Chronologically.				Order of Magnitude by Years.				Order of Magnitude of Whole Term.			
		A	B	C	D	A	B	C	D	A	B	C	D
1	July.....	.72	.72	.72	.72	.51	.51	.51	.51	.36	.36	.36	.36
2	Sept.....	.92	1.64	.82	.90	.64	1.15	.58	.63	.46	.82	.41	.45
3	June.....	1.00	2.64	.88	.97	.73	1.88	.63	.70	.82	1.44	.48	.59
4	Aug......	1.05	3.69	.92	1.01	.85	2.73	.68	.79	.78	2.22	.55	.71
5	Oct......	1.10	4.79	.96	1.04	1.01	3.74	.75	.90	.99	3.21	.64	.85
6	Nov.....	1.37	6.16	1.03	1.20	1.23	4.97	.83	1.03	1.18	4.39	.73	.96
7	May.....	1.67	7.83	1.12	1.35	1.43	6.40	.91	1.13	1.45	5.84	.83	1.09
8	Dec.	1.83	9.66	1.21	1.42	1.79	8.19	1.02	1.28	1.76	7.60	.95	1.22
9	Jan......	2.26	11.92	1.32	1.56	2.14	10.33	1.15	1.39	2.21	9.81	1.09	1.37
10	Feb.	2.72	14.63	1.46	1.67	2.70	13.03	1.30	1.54	2.73	12.54	1.25	1.50
11	April....	2.80	17.43	1.58	1.69	3.39	16.42	1.49	1.65	3.46	16.00	1.45	1.62
12	March...	3.59	21.02	1.75	1.75	4.60	21.02	1.75	1.75	5.01	21.01	1.75	1.75

TABLE No. 5.

CROTON RIVER, NEW YORK.

THIRTY-EIGHT YEARS, 1869 TO 1905 INCLUSIVE. DRAINAGE AREA 338.8 SQUARE MILES.

Original Data Calculated Monthly.

A. Flow in cubic feet per second per square mile.
B. Number of months this flow occurred in the whole term of years.
C. Number of months this flow and all lower flows combined occurred.
D. Product of each flow by the number of months it occurred (A × B).
E. Sum of products for this flow and all lower flows.
F. Average number of days per year this flow occurred in whole term of years (C × .8 = F).
G. Average flow of all days below and including this flow.
H. Average flow for the whole year with development equal to this flow,

$$\frac{(365 - F)\ A + (F \times G)}{365}$$

A	B	C	D	E	F	G	H
.10	1	1	.10	.10	1	.10	.10
.16	1	2	.16	.26	2	.13	.16
.26	1	3	.26	.52	3	.17	.26
.27	2	5	.54	1.06	4	.21	.27
.28	1	6	.28	1.34	5	.22	.28

A	B	C	D	E	F	G	H
.29	1	7	.29	1.63	6	.23	.29
.30	1	8	.30	1.93	7	.24	.30
.33	2	10	.66	2.59	8	.26	.33
.35	1	11	.35	2.94	9	.27	.35
.36	2	13	.72	3.66	10	.28	.36
.37	2	15	.74	4.40	12	.29	.37
.38	4	19	1.52	5.92	15	.31	.38
.39	8	27	3.12	9.04	22	.33	.39
.41	11	38	4.51	13.55	30	.35	.40
.42	3	41	1.26	14.81	33	.36	.41
.43	4	45	1.72	16.53	36	.37	.42
.44	4	49	1.76	18.29	39	.37	.43
.45	3	52	1.35	19.64	41	.38	.44
.46	7	59	3.22	22.86	47	.39	.45
.47	3	62	1.41	24.27	49	.39	.46
.48	4	66	1.92	26.19	53	.40	.47
.49	2	68	.98	27.17	54	.40	.48
.50	2	70	1.00	28.17	56	.40	.49
.52	2	72	1.04	29.21	57	.41	.50
.53	4	76	2.12	31.33	60	.41	.51
.54	3	79	1.62	32.95	63	.42	.52
.55	4	83	2.20	35.15	66	.42	.53
.56	2	85	1.12	36.27	68	.43	.54
.57	1	86	.57	36.84	69	.43	.55
.59	1	87	.59	37.43	70	.43	.56
.61	1	88	.61	38.04	71	.43	.57
.62	2	90	1.24	39.28	72	.44	.58
.63	4	94	2.52	41.80	75	.44	.59
.64	5	99	3.20	45.00	79	.45	.60
.65	2	101	1.30	46.30	81	.46	.61
.66	2	103	1.32	47.62	82	.46	.61
.67	5	108	3.35	50.97	86	.47	.62
.68	2	110	1.36	52.33	88	.48	.63
.69	3	113	2.07	54.40	90	.48	.64
.70	2	115	1.40	55.80	92	.49	.64
.71	1	116	.71	56.51	93	.49	.65
.72	3	119	2.16	58.67	95	.49	.65
.73	1	120	.73	59.40	96	.50	.66
.74	6	126	4.44	63.84	100	.51	.68
.75	5	131	3.75	67.89	105	.52	.68
.76	1	132	.76	68.35	106	.52	.69
.77	2	134	1.54	69.89	107	.52	.70
.78	3	137	2.34	72.23	110	.53	.70
.79	1	138	.79	73.02	110	53	.72
.80	1	139	.80	73.82	111	.53	.72
.81	1	140	.81	74.63	112	.53	.72
.82	1	141	.82	75.45	113	.54	.73
.83	1	142	.83	76.38	114	.54	.74
.84	1	143	.84	77.12	115	.54	.75
.85	3	146	2.55	79.67	117	.55	.75
.86	2	148	1.72	81.39	118	.55	.76
.87	1	149	.87	82.26	119	.55	.76
.88	2	151	1.76	84.02	121	.56	.77

A	B	C	D	E	F	G	H
.89	1	152	.89	84.91	122	.56	.78
.91	3	155	2.73	87.64	124	.57	.79
.92	3	158	2.76	90.40	126	.57	.80
.93	1	159	.93	91.33	127	.57	.80
.94	2	161	1.88	93.21	129	.58	.82
.95	3	164	2.85	96.06	131	.59	.82
.96	1	165	.96	97.02	132	.59	.83
.97	1	166	.97	97.99	133	.60	.83
.98	4	170	3.92	101.91	136	.60	.84
.99	2	172	1.98	103.89	138	.60	.84
1.01	3	175	3.03	106.92	140	.60	.85
1.02	7	176	1.02	107.94	141	.60	.86
1.03	6	182	6.18	114.12	145	.63	.87
1.04	6	188	6.24	120.36	150	.64	.88
1.05	2	190	2.10	122.46	152	.64	.88
1.06	2	192	2.12	124.58	154	.65	.89
1.07	1	193	1.07	125.65	154	.65	.89
1.08	3	196	3.24	129.89	157	.66	.90
1.09	1	197	1.09	129.98	158	.66	.90
1.10	2	199	2.20	132.18	159	.66	.91
1.11	3	202	3.33	135.51	162	.67	.91
1.12	1	203	1.12	136.63	162	.67	.92
1.13	1	204	1.13	137.76	163	.68	.93
1.15	3	207	3.45	141.21	166	.68	.94
1.17	2	209	2.34	143.55	167	.69	.95
1.18	1	210	1.18	144.73	168	.69	.95
1.19	1	211	1.19	145.92	169	.69	.96
1.21	2	213	2.42	148.34	170	.70	.97
1.23	4	217	4.92	153.26	174	.70	.98
1.24	1	218	1.24	154.50	174	.70	.98
1.25	3	221	3.75	158.25	177	.72	.99
1.26	1	222	1.26	159.51	177	.72	1.00
1.27	1	223	1.27	160.78	178	.72	1.00
1.29	1	224	1.29	162.07	179	.72	1.01
1.30	1	225	1.30	163.37	180	.73	1.02
1.31	2	227	2.62	165.99	181	.73	1.02
1.32	1	228	1.32	167.31	182	.73	1.03
1.33	3	231	3.99	177.30	185	.74	1.03
1.34	3	234	4.12	175.32	187	.75	1.04
1.35	1	235	1.35	176.67	188	.75	1.04
1.36	3	238	4.08	180.75	190	.76	1.05
1.38	2	240	2.76	183.51	192	.76	1.05
1.39	1	241	1.39	184.90	193	.77	1.06
1.42	2	243	2.84	187.74	194	.78	1.06
1.44	1	244	1.44	189.18	195	.78	1.07
1.45	2	245	2.90	192.08	197	.78	1.09
1.46	2	248	2.92	195.00	198	.79	1.10
1.47	2	250	2.94	197.94	200	.79	1.10
1.49	4	254	5.96	203.90	203	.80	1.11
1.52	1	255	1.52	205.42	204	.81	1.12
1.53	3	258	4.59	210.01	206	.81	1.12
1.54	2	260	3.08	213.09	208	.82	1.13
1.55	1	261	1.55	215.64	209	.82	1.13

A	B	C	D	E	F	G	H
1.56	2	263	3.12	218.76	210	.83	1.14
1.57	2	265	3.14	221.90	212	.84	1.14
1.58	1	266	1.58	222.48	213	.84	1.15
1.59	1	267	1.59	224.07	214	.84	1.15
1.62	3	270	4.86	228.93	216	.85	1.16
1.63	1	271	1.63	230.56	217	.85	1.17
1.64	1	272	1.64	232.20	217	.85	1.17
1.65	2	274	3.30	235.50	219	.86	1.18
1.66	1	275	1.66	237.16	220	.86	1.18
1.67	3	278	5.01	242.17	222	.87	1.18
1.69	2	280	3.28	245.45	224	.88	1.19
1.71	1	281	1.71	247.16	225	.88	1.20
1.72	1	282	1.72	248.88	225	.88	1.20
1.73	1	283	1.73	250.61	226	.89	1.21
1.74	3	286	5.22	255.83	228	.89	1.21
1.76	1	287	1.76	257.59	230	.90	1.22
1.77	2	289	3.54	261.13	231	.90	1.22
1.78	2	291	3.56	264.69	233	.91	1.23
1.79	1	292	1.79	266.48	233	.91	1.23
1.81	1	293	1.81	268.29	234	.92	1.23
1.83	1	294	1.83	270.12	235	.92	1.24
1.85	11	295	1.85	270.97	236	.92	1.25
1.87	1	296	1.87	272.84	237	.92	1.25
1.90	2	298	3.80	276.64	238	.93	1.27
1.92	1	299	1.92	278.56	239	.93	1.27
1.93	2	301	3.86	282.42	241	.94	1.28
1.94	1	302	1.94	284.36	242	.94	1.28
1.95	1	303	1.95	286.31	242	.94	1.28
2.00	2	305	4.00	290.31	244	.95	1.30
2.01	2	307	4.02	294.33	246	.96	1.30
2.04	1	308	2.04	296.37	246	.96	1.31
2.07	2	310	4.14	300.51	248	.97	1.32
2.08	1	311	2.08	302.59	249	.97	1.32
2.09	4	315	8.36	311.95	252	.99	1.33
2.10	1	316	2.10	314.05	253	.99	1.33
2.12	2	318	4.24	318.29	254	1.00	1.34
2.13	1	319	2.13	320.42	255	1.00	1.34
2.17	1	320	2.17	322.59	256	1.01	1.35
2.18	1	321	2.18	324.77	257	1.01	1.36
2.19	1	322	2.19	326.96	258	1.01	1.36
2.21	1	323	2.21	329.17	258	1.02	1.37
2.24	2	325	4.48	333.65	260	1.03	1.37
2.25	1	326	2.25	335.90	261	1.03	1.37
2.26	2	328	4.52	340.42	262	1.04	1.38
2.28	1	329	2.28	342.70	263	1.04	1.39
2.29	1	330	2.29	344.99	264	1.05	1.39
2.31	1	331	2.31	347.30	265	1.05	1.39
2.32	2	333	4.64	351.94	266	1.06	1.40
2.34	2	335	4.68	356.62	268	1.06	1.40
2.35	1	336	2.35	358.97	269	1.07	1.40
2.36	2	338	4.72	363.69	270	1.08	1.41
2.37	1	339	2.37	366.06	271	1.08	1.41
2.40	1	340	2.40	368.46	272	1.08	1.42

A	B	C	D	E	F	G	H
2.41	1	341	2.41	370.87	273	1.09	1.42
2.44	2	343	4.88	375.75	274	1.09	1.43
2.45	1	344	2.45	378.20	275	1.10	1.43
2.47	1	345	2.47	380.67	276	1.10	1.44
2.49	2	347	4.98	385.65	278	1.11	1.44
2.54	1	348	2.54	388.19	278	1.12	1.45
2.55	1	349	2.55	390.74	279	1.12	1.46
2.57	1	350	2.57	393.31	280	1.12	1.46
2.60	1	351	2.60	395.91	281	1.12	1.46
2.62	2	353	5.24	401.15	282	1.13	1.47
2.64	1	354	2.64	403.79	283	1.14	1.48
2.65	1	355	2.65	406.44	284	1.14	1.48
2.67	2	357	5.34	411.78	286	1.15	1.48
2.68	3	360	8.04	419.82	288	1.16	1.48
2.69	1	361	2.69	422.51	289	1.17	1.49
2.71	2	363	5.42	427.93	290	1.17	1.49
2.74	1	364	2.74	430.67	291	1.18	1.50
2.75	2	366	5.50	436.17	293	1.19	1.50
2.81	1	367	2.81	438.98	294	1.19	1.51
2.82	2	369	5.64	444.62	295	1.20	1.51
2.83	1	370	2.83	447.45	296	1.20	1.51
2.85	1	371	2.85	450.30	297	1.21	1.52
2.88	1	372	2.88	453.18	298	1.21	1.52
2.89	1	373	2.89	456.07	298	1.21	1.52
2.94	1	374	2.94	459.01	299	1.21	1.52
2.95	1	375	2.95	461.96	300	1.23	1.54
2.97	1	376	2.97	464.93	301	1.23	1.54
2.98	3	379	8.94	473.87	303	1.23	1.54
3.00	1	380	3.00	476.87	304	1.25	1.54
3.02	1	381	3.02	479.89	305	1.26	1.55
3.04	2	383	6.08	485.97	306	1.27	1.56
3.07	2	385	6.14	492.11	308	1.27	1.56
3.11	1	386	3.11	495.22	309	1.28	1.56
3.14	1	387	3.14	498.36	310	1.28	1.56
3.15	2	389	6.30	504.66	311	1.29	1.57
3.17	1	390	3.17	507.83	312	1.29	1.58
3.24	1	391	3.24	511.07	313	1.30	1.58
3.28	1	392	3.28	514.35	314	1.31	1.59
3.29	1	393	3.29	517.64	314	1.31	1.59
3.30	1	394	3.30	520.94	315	1.32	1.59
3.31	2	396	6.62	527.56	317	1.33	1.59
3.33	1	397	3.33	530.89	318	1.33	1.59
3.38	1	398	3.38	534.27	318	1.34	1.60
3.39	1	399	3.39	537.66	319	1.34	1.60
3.45	2	401	6.90	544.56	321	1.36	1.61
3.55	2	403	7.10	551.66	322	1.37	1.63
3.56	1	404	3.56	555.22	323	1.37	1.63
3.59	1	405	3.59	558.81	324	1.38	1.63
3.70	3	408	11.10	569.91	326	1.39	1.64
3.75	1	409	3.75	573.66	327	1.40	1.65
3.76	1	410	3.76	577.42	328	1.41	1.65
3.79	2	412	7.58	585.00	330	1.42	1.65
3.80	1	413	3.80	588.80	330	1.42	1.65

A	B	C	D	E	F	G	H
3.81	1	414	3.81	592.61	331	1.43	1.65
3.86	1	415	3.86	596.47	332	1.43	1.65
3.89	1	416	3.89	600.36	333	1.44	1.66
3.91	1	417	3.91	604.27	334	1.45	1.66
3.96	1	418	3.96	608.23	334	1.45	1.66
4.03	2	420	8.06	616.29	336	1.47	1.67
4.06	1	421	4 06	620.35	337	1.47	1.67
4.08	2	423	8.16	628.51	338	1.48	1.67
4.13	1	424	4.13	632.64	339	1.49	1.68
4.22	2	426	8.44	641.08	341	1.50	1.68
4.25	1	427	4.25	645.33	342	1.51	1.68
4.32	1	428	4.32	649.65	342	1.52	1.69
4.34	1	429	4.34	653.99	343	1.52	1.69
4.35	1	430	4.35	658.34	344	1.53	1.69
4.41	1	431	4.41	662.75	345	1.54	1.70
4.42	1	432	4.42	667.17	346	1.54	1.70
4.47	1	433	4.47	671.64	346	1.55	1.70
4.51	1	434	4.51	676.15	347	1.56	1.71
4.62	1	435	4.62	680.77	348	1.56	1.71
4.64	1	436	4.64	685.41	349	1.57	1.71
4.69	1	437	4.69	690.10	350	1.58	1.71
4.73	1	438	4.73	694.83	350	1.58	1.71
4.77	2	440	9.54	704.37	352	1.59	1.71
4.79	2	442	9.58	713.95	354	1.61	1.71
5.03	1	443	5.03	718.98	354	1.61	1.71
5.09	1	444	5.09	724.07	355	1.62	1.71
5.19	1	445	5.19	729.26	356	1.63	1.71
5.24	1	446	5.24	734.50	357	1.64	1.72
5.37	1	447	5.37	739.87	358	1.65	1.72
5.52	1	448	5.52	745.39	358	1.66	1.73
5.62	1	449	5.62	751.01	359	1.67	1.74
5.79	1	450	5.79	756.80	360	1.68	1.74
6.06	2	452	12.12	768.92	362	1.70	1.74
6.26	1	453	6.26	775.18	362	1.71	1.75
6.78	1	454	6.78	781.96	363	1.72	1.75
8.19	1	455	8.19	790.15	364	1.73	1.75
8.55	1	456	8.55	798.70	365	1.75	1.75

TABLE No. 6.

Connecticut River at Holyoke, Mass.

C. F. S. = Cubic feet per second on the watershed of 8 660 square miles.
C. F. S. S. M. = Cubic feet per second per square mile.

First column under each year is number of days each flow occurred.
Second column under each year gives number of days each flow was not exceeded.

Table prepared by C. F. Chandler and S. B. Palmer, Norwich, Conn., from data by A. F. Sickman, Holyoke, Mass.

C. F. S.	C. F. S. S. M.	1881		1882		1883		1884		1885		1886		1887		1888		1889		1890		1891		1892		1893		1894		1895		1896		1897		1898		1899		Total.		Average.		C. F. S.	C. F. S. S. M.
1 600	0.1847	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	7	0	0	0	0	0	0	0	0	0	0	7	7	0.4	0.4	1 600	0.1847
1 650	0.1905	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	7	0	0	0	0	0	0	0	0	0	0	3	10	0.2	0.6	1 650	0.1905
1 700	0.1963	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	3	0	7	0	0	0	0	0	0	0	0	0	0	1	11	0.0	0.6	1 700	0.1963
1 750	0.2021	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	7	0	0	0	0	0	0	0	0	0	0	0	11	0.0	0.6	1 750	0.2021
1 800	0.2078	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	8	0	0	0	0	0	0	0	0	0	0	2	13	0.1	0.7	1 800	0.2078
1 850	0.2136	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	8	0	0	0	0	0	0	0	0	0	0	0	13	0.0	0.7	1 850	0.2136
1 900	0.2194	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	7	15	0	0	1	1	0	0	0	0	0	0	8	21	0.4	1.1	1 900	0.2194
1 950	0.2252	0	0	0	0	7	8	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	15	0	0	0	1	0	0	0	0	0	0	7	28	0.4	1.5	1 950	0.2252
2 000	0.2309	0	0	0	0	0	8	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	15	0	0	0	1	0	0	0	0	0	0	0	28	0.0	1.5	2 000	0.2309
2 050	0.2367	0	0	0	0	0	8	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	17	0	0	3	4	0	0	0	0	0	0	6	34	0.3	1.8	2 050	0.2367
2 100	0.2425	0	0	0	0	0	8	0	0	0	0	7	9	0	0	0	0	0	0	1	1	0	0	0	0	0	3	0	17	0	0	1	5	0	0	0	0	0	0	9	43	0.5	2.3	2 100	0.2425
2 150	0.2483	0	0	0	0	7	15	0	0	0	0	1	10	0	0	0	0	0	0	0	1	0	0	0	0	0	3	0	17	0	0	0	5	0	0	0	0	0	0	8	51	0.4	2.7	2 150	0.2483
2 200	0.2540	0	0	0	0	0	15	0	0	0	0	0	10	0	0	0	0	0	0	0	1	0	0	0	0	0	3	0	17	0	0	0	5	0	0	0	0	0	0	0	51	0.0	2.7	2 200	0.2540
2 250	0.2598	0	0	0	0	7	22	0	0	0	0	1	11	0	0	0	0	0	0	0	1	0	0	0	0	0	3	2	19	0	0	0	5	0	0	0	0	6	6	16	67	0.8	3.5	2 250	0.2598
2 300	0.2656	0	0	0	0	7	29	0	0	0	0	3	14	0	0	0	0	0	0	0	1	0	0	0	0	0	3	7	26	0	0	1	6	1	1	0	0	0	6	19	86	1.0	4.5	2 300	0.2656
2 350	0.2714	0	0	2	2	2	31	0	0	0	0	1	15	0	0	0	0	1	1	1	2	0	0	0	0	0	3	7	33	0	0	2	8	0	1	0	0	14	20	30	116	1.6	6.1	2 350	0.2714
2 400	0.2771	0	0	8	10	2	33	0	0	0	0	1	16	0	0	0	0	0	1	0	2	0	0	0	0	0	3	1	34	0	0	0	8	0	1	0	0	7	27	19	135	1.0	7.1	2 400	0.2771
2 450	0.2829	0	0	2	12	1	34	0	0	0	0	2	18	0	0	1	1	0	1	0	2	0	0	0	0	1	4	7	41	0	0	0	8	0	1	0	0	0	27	14	149	0.7	7.8	2 450	0.2820
2 500	0.2887	0	0	2	14	2	36	0	0	0	0	7	25	0	0	0	1	0	1	0	2	0	0	0	0	0	4	0	41	2	2	0	8	0	1	0	0	9	36	22	171	1.2	9.0	2 500	0.2887
2 550	0.2945	0	0	3	17	0	36	0	0	0	0	4	29	0	0	2	3	0	1	0	2	0	0	1	1	2	6	2	43	0	2	1	9	0	1	0	0	7	43	22	193	1.2	10.2	2 550	0.2945
2 600	0.3002	0	0	1	18	3	39	0	0	0	0	1	30	0	0	0	3	0	1	1	3	0	0	0	1	4	10	0	43	2	4	0	9	0	1	0	0	0	43	12	205	0.6	10.8	2 600	0.3002
2 650	0.3060	0	0	0	18	1	40	9	9	0	0	2	32	0	0	1	4	0	1	0	3	0	0	0	1	1	11	2	45	0	4	2	11	0	1	0	0	0	43	18	223	0.9	11.7	2 650	0.3060
2 700	0.3118	12	12	0	18	1	41	7	16	0	0	7	39	0	0	0	4	3	4	0	3	0	0	0	1	1	12	0	45	9	13	4	15	0	1	0	0	8	51	52	275	2.7	14.4	2 700	0.3118
2 750	0.3176	0	12	2	20	6	47	0	16	0	0	1	40	0	0	0	4	0	4	2	5	7	7	1	2	1	13	4	49	0	13	0	15	0	1	0	0	0	51	24	299	1.3	15.7	2 750	0.3176
2 800	0.3233	0	12	1	21	7	54	7	23	0	0	5	45	0	0	0	4	0	4	0	5	0	7	0	2	1	14	0	49	3	16	8	23	0	1	0	0	7	58	39	338	2.0	17.7	2 800	0.3233
2 850	0.3291	8	20	11	32	8	62	0	23	0	0	1	46	0	0	0	4	0	4	3	8	2	9	1	3	2	16	2	51	8	24	3	26	0	1	0	0	2	60	51	389	2.7	20.4	2 850	0.3291
2 900	0.3349	0	20	2	34	5	67	1	24	0	0	6	52	0	0	1	5	0	4	1	9	9	18	0	3	2	18	0	51	4	28	1	27	1	2	0	0	0	60	33	422	1.7	22.1	2 900	0.3349
2 950	0.3407	53	73	5	39	8	75	2	26	2	2	2	54	0	0	0	5	0	4	0	9	11	29	2	5	1	19	3	54	13	41	1	28	2	4	0	0	1	61	106	528	5.6	27.7	2 950	0.3407
3 000	0.3464	9	82	7	46	3	78	2	28	1	3	3	57	0	0	2	7	0	4	0	9	0	29	2	7	2	21	3	57	9	50	0	28	1	5	1	1	0	61	45	573	2.4	30.1	3 000	0.3464
3 050	0.3522	7	89	5	51	5	83	7	35	1	4	3	60	0	0	0	7	0	4	0	9	3	32	0	7	6	27	4	61	9	59	0	28	2	7	0	1	4	65	56	629	2.9	33.0	3 050	0.3522
3 100	0.3580	10	99	1	52	4	87	2	37	2	6	3	63	0	0	3	10	1	5	1	10	2	34	0	7	4	31	3	64	6	65	0	28	2	9	0	1	1	66	43	674	2.3	35.3	3 100	0.3580
3 150	0.3638	0	99	0	52	0	87	0	37	0	6	6	69	0	0	1	11	0	5	2	12	1	35	0	7	0	31	0	64	14	79	0	28	0	9	0	1	5	71	29	703	1.5	36.8	3 150	0.3638
3 200	0.3695	0	99	7	59	7	94	6	43	1	7	7	76	0	0	0	11	0	5	0	12	1	36	3	10	4	35	0	64	1	80	0	28	1	10	4	5	4	75	46	749	2.4	39.2	3 200	0.3695
3 250	0.3753	0	99	3	62	4	98	0	43	0	7	7	83	0	0	1	12	1	6	0	12	1	37	0	10	9	44	0	64	5	85	0	28	1	11	1	6	7	82	40	789	2.1	41.3	3 250	0.3753
3 300	0.3811	1	100	2	64	6	104	0	43	2	9	5	88	1	1	1	13	1	7	0	12	1	38	0	10	0	44	0	64	5	90	2	30	0	11	4	10	4	86	35	824	1.8	43.1	3 300	0.3811
3 350	0.3869	0	100	1	65	7	111	0	43	0	9	3	91	0	1	0	13	1	8	0	12	3	41	0	10	2	46	5	69	4	94	2	32	5	16	1	11	1	87	35	859	1.8	44.9	3 350	0.3869
3 400	0.3926	1	101	7	72	11	122	0	43	1	10	0	91	0	1	1	14	1	9	0	12	3	44	0	10	3	49	2	71	4	98	1	33	1	17	1	12	2	89	39	898	2.0	46.9	3 400	0.3926
3 450	0.3984	2	103	7	79	7	129	0	43	0	10	3	94	0	1	3	17	2	11	0	12	0	44	1	11	2	51	2	73	1	99	2	35	4	21	5	17	1	90	42	940	2.2	49.1	3 450	0.3984
3 500	0.4042	2	105	9	88	7	136	8	51	1	11	0	94	1	2	2	19	1	12	2	14	1	45	0	11	1	52	0	73	8	107	0	35	2	23	3	20	1	91	49	989	2.6	51.7	3 500	0.4042
3 550	0.4100	0	105	5	93	2	138	0	51	4	15	1	95	2	4	2	21	0	12	1	15	5	50	0	11	0	52	2	75	6	113	0	35	5	28	3	23	3	94	41	1 030	2.2	53.9	3 550	0.4100
3 600	0.4157	12	117	6	99	8	146	8	59	1	16	3	98	0	4	1	22	0	12	1	16	6	56	1	12	3	55	2	77	7	120	1	36	3	31	2	25	0	94	65	1 095	3.4	57.3	3 600	0.4157
3 650	0.4215	0	117	8	107	12	158	6	65	2	18	0	98	1	5	2	24	3	15	4	20	1	57	1	13	3	58	0	77	1	121	4	40	1	32	1	26	1	95	51	1 146	2.7	60.0	3 650	0.4215
3 700	0.4273	7	124	8	115	3	161	1	66	3	21	1	99	4	9	2	26	0	15	7	27	0	57	0	13	1	59	1	78	5	126	2	42	5	37	0	26	2	97	52	1 198	2.7	62.7	3 700	0.4273
3 750	0.4331	3	127	7	122	5	166	0	66	1	22	2	101	6	15	1	27	0	15	2	29	0	57	0	13	8	67	0	78	0	126	3	45	3	40	0	26	2	99	43	1 241	2.3	65.0	3 750	0.4331
3 800	0.4388	2	129	2	124	3	169	2	68	2	24	1	102	3	18	0	27	1	16	1	30	1	58	0	13	8	75	1	79	2	128	5	50	0	40	2	28	0	99	36	1 277	1.9	66.9	3 800	0.4388
3 850	0.4446	3	132	1	125	3	172	0	68	3	27	0	102	1	19	0	27	2	18	1	31	0	58	0	13	3	78	1	80	2	130	0	50	2	42	3	31	2	101	27	1 304	1.4	68.6	3 850	0.4446
3 900	0.4504	0	132	0	125	4	176	2	70	1	28	2	104	1	20	0	27	2	20	0	31	0	58	1	14	7	85	4	84	6	136	5	55	4	46	0	31	2	103	41	1 345	2.2	70.5	3 900	0.4504
3 950	0.4562	1	133	0	125	1	177	2	72	1	29	3	107	0	20	0	27	0	20	0	31	2	60	0	14	3	88	2	86	2	138	0	55	3	49	2	33	1	104	23	1 368	1.2	71.7	3 950	0.4562
4 000	0.4619	1	134	1	126	1	178	6	78	0	29	0	107	1	21	0	27	0	20	2	33	3	63	1	15	4	92	3	89	2	140	3	58	1	50	3	36	3	107	35	1 403	1.8	73.5	4 000	0.4619
4 050	0.4677	1	135	2	128	4	182	3	81	2	31	0	107	2	23	0	27	0	20	0	33	3	66	0	15	4	96	3	92	3	143	1	59	0	50	1	37	2	109	31	1 434	1.6	75.1	4 050	0.4677
4 100	0.4735	3	138	2	130	2	184	3	84	2	33	1	108	0	23	1	28	0	20	1	34	4	70	0	15	1	97	1	93	3	146	3	62	1	51	1	38	3	112	32	1 466	1.7	76.8	4 100	0.4735
4 150	0.4793	2	140	2	132	1	185	4	88	5	38	0	108	2	25	1	29	0	20	0	34	5	75	2	17	3	100	1	94	0	146	4	66	0	51	0	38	3	115	35	1 501	1.8	78.6	4 150	0.4793
4 200	0.4850	1	141	2	134	0	185	1	89	0	38	0	108	3	28	1	30	1	21	0	34	2	77	4	21	2	102	0	94	4	150	2	68	1	52	1	39	1	116	26	1 527	1.4	80.0	4 200	0.4850
4 250	0.4908	0	141	2	136	1	186	2	91	3	41	0	108	4	32	1	31	0	21	0	34	1	78	4	25	5	107	2	96	1	151	3	71	0	52	2	41	1	117	32	1 559	1.7	81.7	4 250	0.4908
4 300	0.4966	1	142	2	138	1	187	1	92	5	46	0	108	1	33	0	31	0	21	1	35	1	79	3	28	3	110	2	98	3	154	6	77	1	53	0	41	1	118	32	1 591	1.7	83.4	4 300	0.4966
4 350	0.5024	1	143	1	139	2	189	5	97	1	47	2	110	0	33	1	32	0	21	2	37	2	81	4	32	5	115	1	99	3	157	2	79	2	55	2	43	0	118	36	1 627	1.9	85.3	4 350	0.5024
4 400	0.5081	1	144	4	143	4	193	3	100	1	48	0	110	2	35	0	32	0	21	1	38	2	83	6	38	6	120	1	100	2	159	4	83	4	59	1	44	3	121	44	1 671	2.3	87.6	4 400	0.5081
4 450	0.5139	0	144	0	143	0	193	0	100	0	48	0	110	2	37	0	32	1	22	1	39	1	84	2	40	1	121	4	104	0	159	4	87	4	63	1	45	0	121	21	1 692	1.1	88.7	4 450	0.5139
4 500	0.5197	0	144	1	144	1	194	1	101	1	49	0	110	1	38	0	32	0	22	0	39	3	87	4	44	3	124	2	106	2	161	3	90	1	64	1	46	2	123	26	1 718	1.4	90.1	4 500	0.5197
4 550	0.5255	1	145	0	144	1	195	0	101	0	49	1	111	1	39	0	32	1	23	2	41	1	88	2	46	3	127	2	108	4	165	4	94	2	66	1	47	1	124	27	1 745	1.4	91.5	4 550	0.5255
4 600	0.5312	0	145	0	144	2	197	2	103	2	51	0	111	3	42	0	32	0	23	0	41	4	92	0	46	2	129	4	112	2	167	1	95	0	66	2	49	3	127	27	1 772	1.4	92.9	4 600	0.5312
4 650	0.5370	1	146	0	144	4	201	1	104	2	53	0	111	0	42	0	32	1	24	0	41	4	96	3	49	4	133	2	114	0	167	4	99	3	69	1	50	2	129	32	1 804	1.7	94.6	4 650	0.5370
4 700	0.5428	1	147	0	144	3	204	1	105	1	54	1	112	1	43	0	32	0	24	1	42	1	97	4	53	3	136	4	118	3	170	1	100	4	73	2	52	0	129	31	1 835	1.6	96.2	4 700	0.5428
4 750	0.5486	3	150	2	146	1	205	0	105	2	56	0	112	0	43	2	34	0	24	1	43	0	97	1	54	1	137	6	124	5	175	2	102	1	74	3	55	2	131	32	1 867	1.7	97.9	4 750	0.5486
4 800	0.5543	0	150	2	148	2	207	1	106	1	57	0	112	2	45	1	35	0	24	1	44	0	97	1	55	4	141	9	133	1	176	2	104	2	76	2	57	1	132	32	1 899	1.7	99.6	4 800	0.5543
4 850	0.5601	0	150	2	150	2	209	3	109	6	63	0	112	2	47	0	35	0	24	0	44	2	99	1	56	2	143	3	136	3	179	2	106	3	79	2	59	2	134	35	1 934	1.8	101.4	4 850	0.5601
4 900	0.5659	0	150	3	153	2	211	4	113	1	64	1	113	0	47	2	37	1	25	0	44	0	99	2	58	4	147	1	137	1	180	1	107	5	84	0	59	1	135	29	1 963	1.5	102.9	4 900	0.5659
4 950	0.5717	2	152	2	155	2	213	2	115	2	66	0	113	0	47	1	38	0	25	0	44	1	100	2	60	2	149	3	140	2	182	0	107	4	88	0	59	1	136	26	1 989	1.4	104.3	4 950	0.5717
5 000	0.5774	2	154	2	157	4	217	1	116	3	69	0	113	0	47	0	38	0	25	0	44	3	103	3	63	0	149	4	144	0	182	1	108	1	89	1	60	2	138	27	2 016	1.4	105.7	5 000	0.5774
5 050	0.5831	1	155	2	159	0	217	1	117	2	71	0	113	0	47	0	38	0	25	1	45	2	105	2	65	2	151	5	149	1	183	2	110	1	90	3	63	2	140	27	2 043	1.4	107.1	5 050	0.5831
5 100	0.5899	1	156	1	160	0	217	2	119	4	75	1	114	0	47	0	38	0	25	2	47	4	109	3	68	0	151	3	152	1	184	1	111	4	94	0	63	4	144	31	2 074	1.6	108.7	5 100	0.5889
5 150	0.5947	1	157	0	160	2	219	1	120	1	76	1	115	1	48	0	38	0	25	0	47	3	112	2	70	1	152	3	155	3	187	1	112	1	95	0	63	6	150	27	2 101	1.4	110.1	5 150	0.5947
5 200	0.6004	4	161	0	160	0	219	3	123	0	76	0	115	0	48	0	38	1	26	2	49	1	113	1	71	3	155	1	156	2	189	1	113	1	96	0	63	4	154	24	2 125	1.3	111.4	5 200	0.6004
5 250	0.6062	1	162	0	160	1	220	1	124	2	78	0	115	0	48	0	38	0	26	1	50	3	116	3	74	4	159	4	160	1	190	2	115	1	97	0	63	4	158	28	2 153	1.5	112.9	5 250	0.6062
5 300	0.6120	0	162	0	160	0	220	2	126	1	79	0	115	2	50	4	42	1	27	2	52	1	117	0	74	2	161	0	160	0	190	0	115	1	98	0	63	5	163	21	2 174	1.1	114.0	5 300	0.6120
5 350	0.6178	1	163	0	160	0	220	2	128	3	82	0	115	0	50	1	43	0	27	2	54	3	120	1	75	0	161	3	163	0	190	2	117	0	98	1	64	4	167	23	2 197	1.2	115.2	5 350	0.6178
5 400	0.6235	1	164	2	162	1	221	1	129	3	85	0	115	1	51	0	43	0	27	1	55	1	121	1	76	1	162	1	164	1	191	0	117	0	98	0	64	5	172	20	2 217	1.1	116.3	5 400	0.6235
5 450	0.6293	0	164	0	162	0	221	5	134	4	89	1	116	0	51	0	43	0	27	0	55	3	124	0	76	1	163	4	168	0	191	0	117	0	98	1	65	3	175	22	2 239	1.2	117.5	5 450	0.6293
5 500	0.6351	2	166	0	162	0	221	1	135	2	91	1	117	1	52	1	44	0	27	0	55	0	124	0	76	0	163	1	169	0	191	1	118	0	98	1	66	3	178	14	2 253	0.7	118.2	5 500	0.6351
5 550	0.6409	1	167	0	162	0	221	0	135	3	94	0	117	2	54	0	44	0	27	1	56	1	125	3	79	0	163	0	169	3	194	3	121	0	98	0	66	1	179	18	2 271	0.9	119.1	5 550	0.6409
5 600	0.6466	1	168	3	165	0	221	3	138	2	96	0	117	0	54	0	44	1	28	0	56	2	127	1	80	1	164	1	170	1	195	0	121	0	98	1	67	1	180	18	2 289	0.9	120.0	5 600	0.6466
5 650	0.6524	0	168	0	165	1	222	6	144	1	97	0	117	3	57	3	47	0	28	0	56	1	128	0	80	3	167	2	172	1	196	0	121	0	98	0	67	3	183	24	2 313	1.3	121.3	5 650	0.6524
5 700	0.6582	1	169	1	166	1	223	4	148	2	99	0	117	1	58	1	48	0	28	0	56	1	129	1	81	0	167	3	175	1	197	1	122	1	99	0	67	1	184	20	2 333	1.1	122.4	5 700	0.6582
5 750	0.6640	0	169	1	167	1	224	1	149	0	99	0	117	1	59	2	50	2	30	0	56	1	130	1	82	1	168	2	177	0	197	0	122	0	99	1	68	0	184	14	2 347	0.7	123.1	5 750	0.6640
5 800	0.6697	0	169	0	167	1	225	0	149	2	101	1	118	0	59	2	52	2	32	1	57	0	130	1	83	3	171	2	179	1	198	3	125	0	99	1	69	0	184	20	2 367	1.1	124.2	5 800	0.6697
5 850	0.6755	0	169	3	170	0	225	2	151	1	102	2	120	2	61	0	52	0	32	1	58	0	130	1	84	0	171	1	180	1	199	1	126	0	99	2	71	3	187	20	2 387	1.1	125.3	5 850	0.6755
5 900	0.6813	1	170	1	171	0	225	1	152	1	103	0	120	0	61	1	53	1	33	0	58	1	131	2	86	3	174	0	180	1	200	1	127	0	99	0	71	0	187	14	2 401	0.7	126.0	5 900	0.6813
5 950	0.6871	1	171	1	172	1	226	1	153	2	105	1	121	0	61	1	54	3	36	4	62	0	131	1	87	5	179	2	182	1	201	2	129	1	100	1	72	1	188	29	2 430	1.5	127.5	5 950	0.6871
6 000	0.6928	1	172	0	172	2	228	1	154	1	106	0	121	1	62	1	55	0	36	0	62	4	135	0	87	2	181	2	184	2	203	1	130	0	100	1	73	0	188	19	2 449	1.0	128.5	6 000	0.6928
6 050	0.6986	0	172	1	173	1	229	1	155	0	106	1	122	0	62	2	57	1	37	1	63	3	138	3	90	1	182	1	185	3	206	3	133	0	100	2	75	1	189	25	2 474	1.3	129.8	6 050	0.6986
6 100	0.7044	1	173	0	173	0	229	2	157	1	107	1	123	4	66	0	57	0	37	0	63	2	140	1	91	1	183	2	187	0	206	3	136	0	100	0	75	1	190	19	2 493	1.0	130.8	6 100	0.7044
6 150	0.7102	0	173	0	173	0	229	0	157	2	109	2	125	2	68	1	58	2	39	0	63	1	141	3	94	1	184	0	187	1	207	1	137	2	102	3	78	0	190	21	2 514	1.1	131.9	6 150	0.7102
6 200	0.7159	0	173	1	174	0	229	2	159	1	110	1	126	3	71	0	58	0	39	1	64	1	142	2	96	0	184	1	188	3	210	3	140	1	103	0	78	2	192	22	2 536	1.2	133.1	6 200	0.7159
6 250	0.7217	0	173	0	174	2	231	0	159	1	111	0	126	4	75	0	58	2	41	4	68	1	143	2	98	1	185	2	190	2	212	1	141	0	103	1	79	2	194	25	2 561	1.3	134.4	6 250	0.7217
6 300	0.7275	1	174	0	174	1	232	0	159	3	114	0	126	1	76	3	61	2	43	1	69	0	143	1	99	2	187	1	191	3	215	1	142	0	103	1	80	2	196	23	2 584	1.2	135.6	6 300	0.7275
6 350	0.7333	1	175	0	174	0	232	0	159	0	114	1	127	0	76	1	62	1	44	1	70	0	143	2	101	0	187	1	192	0	215	2	144	0	103	0	80	0	196	10	2 594	0.5	136.1	6 350	0.7333
6 400	0.7390	0	175	3	177	0	232	0	159	1	115	0	127	1	77	3	65	0	44	1	71	3	146	4	105	1	188	0	192	1	216	2	146	0	103	1	81	0	196	21	2 615	1.1	137.2	6 400	0.7390
6 450	0.7448	1	176	1	178	1	233	0	159	0	115	1	128	2	79	3	68	1	45	0	71	0	146	0	105	3	191	0	192	0	216	2	148	1	104	0	81	0	196	16	2 631	0.8	138.0	6 450	0.7448
6 500	0.7506	1	177	1	179	1	234	1	160	4	119	0	128	2	81	1	69	2	47	1	72	2	148	1	106	3	194	4	196	0	216	2	150	1	105	2	83	1	197	30	2 661	1.6	139.6	6 500	0.7506
6 550	0.7564	2	179	1	180	2	236	1	161	0	119	1	129	2	83	1	70	2	49	1	73	1	149	1	107	1	195	3	199	0	216	2	152	0	105	1	84	0	197	22	2 683	1.2	140.8	6 550	0.7564
6 600	0.7621	2	181	3	183	2	238	0	161	1	120	2	131	3	86	1	71	1	50	2	75	0	149	4	111	0	195	1	200	0	216	3	155	0	105	2	86	1	198	28	2 711	1.5	142.3	6 600	0.7621
6 650	0.7679	3	184	0	183	1	239	0	161	1	121	0	131	2	88	0	71	1	51	0	75	1	150	2	113	0	195	0	200	0	216	0	155	1	106	0	86	0	198	12	2 723	0.6	142.9	6 650	0.7679
6 700	0.7737	2	186	0	183	0	239	2	163	5	126	1	132	2	90	2	73	0	51	0	75	0	150	0	113	2	197	1	201	0	216	0	155	0	106	1	87	0	198	18	2 741	0.9	143.8	6 700	0.7737
6 750	0.7795	0	186	0	183	1	240	0	163	1	127	0	132	0	90	3	76	0	51	2	77	1	151	2	115	0	197	1	202	0	216	0	155	0	106	0	87	1	199	12	2 753	0.6	144.4	6 750	0.7795
6 800	0.7852	3	189	0	183	1	241	0	163	2	129	3	135	1	91	1	77	0	51	0	77	2	153	0	115	0	197	0	202	0	216	2	157	0	106	0	87	0	199	15	2 768	0.8	145.2	6 800	0.7852
6 850	0.7910	0	189	0	183	1	242	2	165	1	130	3	138	0	91	4	81	2	53	1	78	2	155	2	117	2	199	4	206	0	216	2	159	0	106	1	88	1	200	28	2 796	1.5	146.7	6 850	0.7910
6 900	0.7968	0	189	0	183	0	242	1	166	0	130	0	138	0	91	0	81	3	56	0	78	1	156	0	117	1	200	1	207	0	216	2	161	0	106	1	89	0	200	10	2 806	0.5	147.2	6 900	0.7968
6 950	0.8026	0	189	1	184	0	242	1	167	2	132	0	138	0	91	2	83	1	57	0	78	1	157	1	118	0	200	1	208	0	216	1	162	0	106	2	91	1	201	14	2 820	0.7	147.9	6 950	0.8026
7 000	0.8083	0	189	1	185	1	243	1	168	0	132	0	138	0	91	5	88	2	59	1	79	0	157	2	120	2	202	0	208	1	217	0	162	0	106	1	92	1	202	18	2 838	0.9	148.8	7 000	0.8083
7 050	0.8141	1	190	2	187	2	245	1	169	1	133	1	139	1	92	3	91	3	62	0	79	0	157	2	122	0	202	2	210	2	219	0	162	0	106	1	93	0	202	22	2 860	1.2	150.0	7 050	0.8141
7 100	0.8199	1	191	1	188	0	245	0	169	1	134	1	140	0	92	3	94	1	63	4	83	0	157	1	123	1	203	0	210	1	220	4	166	0	106	0	93	2	204	21	2 881	1.1	151.1	7 100	0.8199
7 150	0.8257	1	192	0	188	0	245	0	169	1	135	1	141	1	93	3	97	0	63	1	84	0	157	1	124	0	203	1	211	0	220	1	167	0	106	0	93	1	205	12	2 893	0.6	151.7	7 150	0.8257
7 200	0.8314	0	192	0	188	1	246	1	170	1	136	2	143	2	95	1	98	2	65	1	85	2	159	0	124	1	204	1	212	1	221	1	168	0	106	3	96	1	206	21	2 914	1.1	152.8	7 200	0.8314
7 250	0.8372	0	192	0	188	0	246	0	170	2	138	1	144	1	96	4	102	2	67	4	89	1	160	0	124	2	206	1	213	2	223	0	168	1	107	1	97	2	208	24	2 938	1.3	154.1	7 250	0.8372
7 300	0.8430	1	193	1	189	0	246	2	172	0	138	1	145	3	99	3	105	3	70	1	90	1	161	0	124	1	207	0	213	0	223	1	169	0	107	0	97	1	209	19	2 957	1.0	155.1	7 300	0.8430
7 350	0.8488	0	193	0	189	2	248	2	174	0	138	0	145	3	102	1	106	1	71	1	91	1	162	1	125	1	208	1	214	0	223	1	170	0	107	0	97	0	209	15	2 972	0.8	155.9	7 350	0.8488
7 400	0.8545	2	195	0	189	1	249	1	175	2	140	3	148	2	104	2	108	1	72	0	91	1	163	1	126	1	209	3	217	0	223	1	171	0	107	0	97	0	209	21	2 993	1.1	157.0	7 400	0.8545
7 450	0.8603	0	195	1	190	0	249	1	176	1	141	0	148	2	106	0	108	2	74	1	92	0	163	0	126	0	209	0	217	1	224	0	171	0	107	0	97	1	210	10	3 003	0.5	157.5	7 450	0.8603
7 500	0.8661	1	196	2	192	1	250	2	178	3	144	2	150	2	108	0	108	1	75	0	92	2	165	2	128	0	209	0	217	1	225	0	171	1	108	2	99	1	211	23	3 026	1.2	158.7	7 500	0.8661
7 550	0.8719	0	196	2	194	1	251	2	180	1	145	2	152	3	111	1	109	2	77	0	92	0	165	2	130	1	210	2	219	1	226	0	171	2	110	2	101	0	211	24	3 050	1.3	160.0	7 550	0.8719
7 600	0.8776	1	197	0	194	1	252	1	181	0	145	1	153	4	115	1	110	0	77	0	92	2	167	0	130	1	211	1	220	2	228	1	172	0	110	2	103	0	211	18	3 068	0.9	160.9	7 600	0.8776
7 650	0.8834	1	198	0	194	0	252	1	182	1	146	1	154	4	119	2	112	0	77	0	92	0	167	2	132	2	213	1	221	1	229	1	173	1	111	5	108	1	212	24	3 092	1.3	162.2	7 650	0.8834
7 700	0.8892	0	198	0	194	2	254	1	183	3	149	0	154	2	121	1	113	2	79	0	92	1	168	0	132	0	213	1	222	0	229	3	176	0	111	2	110	2	214	20	3 112	1.1	163.3	7 700	0.8892
7 750	0.8950	1	199	1	195	1	255	0	183	4	153	1	155	2	123	1	114	2	81	0	92	0	168	2	134	2	215	0	222	3	232	3	179	0	111	1	111	1	215	25	3 137	1.3	164.6	7 750	0.8950
7 800	0.9007	1	200	0	195	0	255	0	183	3	156	3	158	1	124	0	114	0	81	0	92	0	168	1	135	1	216	2	224	2	234	1	180	0	111	2	113	2	217	19	3 156	1.0	165.6	7 800	0.9007
7 850	0.9065	0	200	1	196	1	256	0	183	2	158	1	159	3	127	1	115	1	82	0	92	1	169	2	137	1	217	1	225	4	238	1	181	1	112	1	114	1	218	23	3 179	1.2	166.8	7 850	0.9065
7 900	0.9123	1	201	0	196	0	256	1	184	2	160	0	159	3	130	2	117	1	83	2	94	0	169	0	137	1	218	0	225	0	238	2	183	0	112	0	114	2	220	17	3 196	0.9	167.7	7 900	0.9123
7 950	0.9181	0	201	0	196	0	256	0	184	0	160	1	160	0	130	0	117	0	83	1	95	0	169	3	140	0	218	0	225	0	238	0	183	1	113	0	114	0	220	6	3 202	0.3	168.0	7 950	0.9181
8 000	0.9238	0	201	0	196	0	256	0	184	2	162	2	162	0	130	2	119	2	85	1	96	0	169	1	141	0	218	1	226	0	238	0	183	0	113	3	117	1	221	15	3 217	0.8	168.8	8 000	0.9238

TABLE No. 7.

Connecticut River, Holyoke, Mass.

Nineteen Years, 1881 to 1899 Inclusive. Drainage Area 8 660 Square Miles.

A. Cubic feet per second per square mile for twenty-four hours that wheels, etc., are designed for.
B. Cubic feet per second per square mile, twenty-four hours' flow in ten hours.
C. Horse-power per foot fall per square mile corresponding with A (80 per cent. efficiency).
D. Horse-power per foot fall per square mile corresponding with B (80 per cent. efficiency).
E. Average number of days yearly on which flows A and B and powers C and D occurred.
F. Average number of days yearly on which flows less than A and B and powers less than C and D occurred.
G. Average flow for twenty-four hours on the days when flow was less than A.
H. Average flow using twenty-four hours' flow in ten hours on the days when flow was less than B.
J. Average horse-power per foot mile for twenty-four hours on the days when flow was less than A.
K. Average horse-power per foot mile using twenty-four hours' flow in ten hours on the days when flow was less than B.
L. Average available flow of full year, twenty-four hours per day with development A.
M. Average available flow of full year using twenty-four hours in ten hours with development B.
N. Average available power of full year, twenty-four hours per day, with development A.
O. Average available power of full year using twenty-four hours in ten hours with development B.
P. Percentage that available flow and power bear to the development A, B, C, and D.

C. F. P. S. P. S. M.		H. P. per Foot Mile.		Number of Days.		Average Flow Short Days.		Average Power Short Days.		Average Flow Available.		Average Power Available.		Per Cent. Available.
24 Hrs. A	24 in 10. B	24 Hrs. C	24 in 10. D	Full. E	Short. F	24 Hrs. G	24 in 10. H	24 Hrs. J	24 in 10. K	24 Hrs. L	24 in 10. M	24 Hrs. N	24 in 10. O	P
0.2	.48	.018	.043	311	1	.19	.46	.018	.042	.20	.48	.018	.044	100
0.3	.72	.027	.065	301	11	.26	.62	.024	.057	.29	.70	.026	.064	98
0.4	.96	.036	.087	260	52	.33	.79	.030	.072	.39	.94	.035	.085	97
0.5	1.20	.046	.109	227	85	.38	.91	.034	.083	.47	1.13	.043	.103	94
0.6	1.44	.055	.131	201	111	.42	1.01	.038	.092	.54	1.30	.049	.117	90
0.7	1.68	.064	.153	181	131	.46	1.10	.042	.100	.60	1.44	.055	.131	86
0.8	1.92	.073	.175	164	148	.49	1.18	.045	.107	.65	1.56	.059	.142	81
0.9	2.16	.082	.197	146	166	.53	1.27	.048	.115	.70	1.68	.064	.153	78
1.0	2.40	.091	.218	133	179	.56	1.34	.051	.122	.75	1.80	.068	.164	75
1.1	2.64	.100	.240	121	191	.59	1.42	.054	.129	.79	1.90	.072	.173	72
1.2	2.88	.109	.262	110	202	.62	1.49	.056	.135	.82	1.97	.075	.179	68
1.3	3.12	.118	.284	102	210	.65	1.56	.059	.142	.86	2.06	.078	.187	66
1.4	3.36	.127	.306	93	219	.68	1.63	.062	.148	.89	2.14	.081	.194	64
1.5	3.60	.136	.327	85	227	.70	1.68	.064	.153	.92	2.21	.084	.201	61
1.6	3.84	.146	.349	77	235	.73	1.75	.066	.159	.94	2.26	.086	.205	59
1.7	4.08	.155	.371	71	241	.76	1.82	.069	.165	.97	2.33	.088	.213	57

Formulated by Chandler & Palmer, Norwich, Conn., from data furnished by A. F. Sickman, hydraulic engineer, Holyoke, Mass.

Rafter in his valuable Water Supply and Irrigation Paper No. 80 says: " What is wanted is a clear statement of the minimum together with the longest period such minimum may be expected to occupy."

This is useful only for a development equal to the minimum flow. It seems to the writer that what is wanted is " The *duration* of *every* flow."

This is what Table No. 6 gives us for the Connecticut at Holyoke. The table is so arranged as to give the available flow at any development each year, as well as for the whole term of nineteen years. In no case is a small flow averaged with a larger flow. Days are averaged, not flows.

In order to make the data of convenient application, the average duration of each flow for the whole term, for different developments from 0.2 second feet per square mile to 1.7 second feet per square mile, has been calculated, and shown in Table No. 7.

In column A has been placed each flow varying by .1 for twenty-four hours, and in column B the same flow concentrated in ten hours. Columns C and D give the same flows in terms of horse power per foot mile with 80 per cent. efficiency. Columns E and F give the average number of short and full days at the developments indicated by A and B. Columns G and H give the average flow of the short days. The difference between A and G and between B and H give the average auxiliary power needed at any development. Columns J and K give the power corresponding to the flow in G and H; columns L and M give the average flow, and N and O the average power available throughout the year at any given development A.

The difference between N and O, as the case may be, and A is the average amount of auxiliary power needed at any development A.

Perhaps the last column P is as useful as any, as it gives at any development the average percentage of that development that is available throughout the year on the Connecticut River, or similar stream.

Table No. 8 for the purpose of comparison, shows the average number of full days and average available percentage of flow and power on several other streams.

TABLE No. 8.

FLOW OF STREAMS.

CONNECTICUT RIVER at Holyoke. Calculations made daily.
MERRIMAC RIVER at Lawrence. Calculations made weekly.
SUDBURY RIVER, near Boston. Calculations made monthly.
NASHUA RIVER at Clinton. Calculations made monthly.
CROTON RIVER near New York. Calculations made monthly.

Cubic Feet per Sec. per Sq. Mile	CONNECTICUT. 19 Years. 1881 to 1899. 8 660 Sq. Miles.		MERRIMAC. 11 Years. 1890 to 1900. 4 553 Sq. Miles.		SUDBURY. 19 Years. 1881 to 1899. 75 Sq. Miles.		NASHUA. 9 Years. 1897 to 1905. 119 Sq. Miles.		CROTON. 19 Years. 1881 to 1899. 338.8 Sq. Miles.	
	Full Days	Per cent ava'lble	Full Days	Per cent ava'lble	Full Days	Per cent ava'lble	Full Days	Per cent ava'lble	Full Days	Per cent ava'lble
.1	312	100	312	100	304	99	312	100	312	100
.2	311	100	312	100	275	96	309	100	312	100
.3	301	98	311	100	258	92	309	99	312	100
.4	260	97	299	99	234	89	289	98	304	100
.5	227	94	261	97	218	86	272	96	281	98
.6	201	90	230	94	208	83	243	94	270	96
.7	181	86	205	91	190	80	228	91	256	95
.8	164	81	188	88	186	78	208	89	229	93
.9	146	78			180	75	194	87	215	90
1.0	133	75			170	73	185	84	195	87
1.1	121	72			162	71	173	81	177	85
1.2	110	68			158	70	170	79	169	83
1.3	102	66			152	69	162	77	160	80
1.4	93	64			145	67	153	75	148	78
1.5	85	61			137	65	142	73	138	76
1.6	77	59			127	64	133	70	134	74
1.7	71	57			122	63	130	68	126	72

The above "full days" were obtained by dividing the total number of days each flow occurred during the whole term of years by the number of years to obtain the average number of days each flow was available.

The percentage was obtained by adding the products of all flows by the number of days they occurred and dividing the sum by the products of the given development multiplied by the whole number of working days in the year.

Computed by Chandler & Palmer, 161 Main Street, Norwich, Conn.

Sudbury and Croton are shown for the same nineteen years as are covered by the Holyoke data. Merrimac and Nashua data for the same years are not available.

It should be remembered in comparing these stream flows, that the Holyoke data are from computations made daily, the Merrimac weekly, and the Sudbury, Nashua, and Croton monthly. It should also be remembered that there is a wide divergence in the size of the drainage areas.

There are, of course, plenty of modifications necessary in applying these figures to streams of a different character and under varying circumstances, but it is hoped that the data and the method of their arrangement may be of some use to some one.

DISCUSSION.

THE PRESIDENT. Mr. Chandler's paper is open for discussion. We should like to hear from Mr. Mixer.

MR. CHARLES A. MIXER.* Gentlemen, I have been much interested in this paper and in these (to me) new methods of analyzing river discharges. Not knowing in advance what was to be presented, I am not prepared to discuss them; but I am certain that I shall apply some of the new things heard to my own records.

These variable discharges should be examined from every point of view and by every method of arrangement, but their natural order should never be discarded after re-arranging them in any other order. On a river, with storage and regulation, and in a latitude where the low-water conditions are divided between two seasons, viz., September and February, and where water is used in the same amount throughout the twenty-four hours a day, the natural order of the discharges remains the best. Simply plotting the daily discharges as they occur is a help to easier and more comprehensive study of them.

I will state for those who may not know, that I am at Rumford Falls, Maine, on the Androscoggin River, with its great Rangeley Lakes storage. The records of the daily discharge here for fifteen years have been published in the Water Supply Papers.

MR. H. K. BARROWS.† Mr. President and Gentlemen, I agree with Mr. Mixer that a paper of this sort should be studied somewhat before discussion is attempted. Certainly Mr. Chandler has presented these data in a new and a very interesting way.

There has been some question in my mind whether or not data of this kind should not also be presented in the original form to be of the most value for all purposes. For a given plant, such as on the Connecticut at Holyoke, the data of flow as arranged by Mr. Chandler are certainly very useful, and one can almost tell at a glance what wheel capacity is warranted, and whether or not it can be profitably increased. If he is dealing with a similar situation on some other river where such data can properly be applied, this form is also convenient.

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* Hydraulic Engineer, Rumford Falls, Me.

† Hydraulic and Sanitary Engineer, Boston, Mass.

Where the storage of water at points above the power site is to be a factor in the distribution of run-off, and perhaps further development of storage is contemplated, we especially desire the natural flow of a river as it occurred. In such investigations the tables as arranged by Mr. Chandler cannot be used, as it is evidently incorrect to consider as successive monthly or weekly discharges those occurring at widely varying times. Thus in a given case, the driest month might perhaps be September, and the next driest January, and it is evidently misleading in computations involving storage to consider monthly discharges in this order.

The reports of the United States Geological Survey usually give run-off in the form of monthly minimum, maximum, and mean discharge, although in some cases the daily discharge is also included. On most of our New England streams the flow during medium and low water times is much affected by pondage at privileges further upstream, and in some cases by storage reservoirs, and the flow on any given day based on the usual gage readings may diverge widely from both the true daily mean for that day and the natural flow of the river for that day. For this reason the *week* is a better unit of time for which to consider run-off, as this is a sufficient period for daily gage height errors to compensate, and it is also the usual cycle of pondage and storage variations.

It seems to me that the tables shown by Mr. Chandler could be with profit constructed on the basis of the week, especially during the low-water portion, and I hope that he will be able to include in his paper the *daily flow* as observed, and upon which his tables are based, to permit of this more extended analysis. The *daily* flow of the Connecticut at Holyoke has never been published by the United States Geological Survey, although the monthly mean, maximum, and minimum has been given, scattered through several reports, covering the period discussed by Mr. Chandler.

The President. Mr. Hale, we should like to hear from you.

Mr. Richard A. Hale.* I think, as the previous speaker has said, that a study of the paper is very desirable before discussing it, because there are so many details in connection with it.

One reason that I adopted on the Merrimac River the unit of

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* Hydraulic Engineer, Lawrence, Mass.

the week for the average flow was on account of the storage reservoirs above us at Lowell, Manchester, and at various other points, as it appeared to give a better index of the flow of the river than taking it for a single day. For instance, on Sundays during a dry season the water is retained at various dams along the river. The driest day in the year, from the actual records as the Geological Survey used to give them, would give perhaps a flow of 50 cubic feet per second from 4 000 square miles, which is inaccurate; it means simply that the water is held back, and is not the normal flow. For this reason, the average of a week eliminates to a great extent these irregularities of storage of water.

In regard to the averages, taking the average by months, it produces a smooth outflow which is very misleading, and I have brought a diagram here which was used at Springfield in the paper on " Water Rights " and is familiar to many of you.* It was used in one of the Nashua River cases, in which the flow was worked up for each individual day for a period of years. This was for one year and it shows the extreme variations. The scale is indicated on the side of diagram. The variation in January and February is from 100 horse-power up to 500 horse-power in about two or three days, owing to unusual freshets at this time.

Now, taking the average of a series of months, you might get apparently a very excellent water-power, when, as a matter of fact, there might be a large freshet that would run off in a short time and there would be a series of days of low water when you would derive very small advantage from water-power.

During the dry months, when a very low flow occurs, we have an example in November where the average would indicate a large power. At the commencement of the month there was only 100 horse-power, and then sudden rains increased the flow through November and December. The monthly average would show a large uniform power, which shows the care that must be taken in using averages in connection with water-power.

Considering also a large development of 425 horse-power at this site, although it might be obtained during the first four or five months, there would be this large gap of perhaps 300 horse-power, which would have to be supplied by steam, so a steam

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* See JOURNAL, September, 1907, page 257.

plant would have to be maintained in connection with the water-plant to maintain constant power.

The whole system of averages must be carefully considered in connection with water-power, and certain allowances made, both for sudden storms, where the water wastes over the dam, and the amount of pondage, and the use of water by parties further up the stream, as the total flow during dry months is not entirely available. But I think the whole system of averaging the minimum flows is the best method, and not averaging by the calendar months; it gives a better index of flow of streams than by any other method.

If a man has a steam engine and a water wheel running together, and connected by a clutch, by which the wheel can be readily disconnected while running the mill, advantage can be taken of varying flows of water with little trouble. If, however, there are such connections that gears have to be moved on the wheel, and changes made at noon or night, when the mill is stopped, the extra work involved may not be compensated for by the use of water. In such cases the available power is not all used, and waste over the dam would naturally follow.

MR. CHARLES W. SHERMAN.* Mr. President, in considering the run-off records of our water supply streams, such as the Sudbury and the Croton, it should always be distinctly borne in mind that the flow is, as Mr. Barrows has put it, in a decidedly artificial condition.

The State Board of Health of Massachusetts has computed from original records the weekly run-off of the Sudbury and Nashua rivers, and published it each year in its yearly report. My own opinion has always been that that was hardly warranted by the conditions of gaging. Those watersheds contain very large storage reservoirs; in some cases during the drier months one-tenth foot of storage would mean the run-off of perhaps a whole month. It is impossible to measure the *exact* height of the water in those reservoirs, and even if that were possible the change of storage represented by a change of height in the reservoirs could be determined only approximately. And as those figures form an important element in computing the run-off of the stream,

* Principal Assistant Engineer, with Metcalf & Eddy, Boston, Mass.

the quantity flowing in a single day (which could be computed mathematically from the records, as well as the quantity for a month) would really mean nothing whatever. My feeling has been that the quantity computed for the week, although not subject to anything like the same percentage of error as would be that for a single day, would still have to be taken with a grain of salt. I think in cases like that, the month is the smallest unit of time that we can logically use.

Of course, in making use of such records, the engineer must bear in mind that the average flow of a month would be exceeded during the month, and there would also be days when the flow was very much less than the average; and he would have to use his judgment in estimating what the probable daily minimum or daily maximum would be.

I think that applies to practically all of the small streams that have been used for water supply purposes. In the case of water-power streams the actual quantity of water flowing in the stream is the main element of the situation, and storage does not cut nearly so large a figure, so that it can frequently be neglected.

Mr. Chandler. The situation in Holyoke is unique in various ways. In the first place, they no longer are making these calculations, on account of the fact that the new dam and the old dam are so near together that it seems impracticable to measure the flow, so this nineteen-year record is all that we are likely to have in relation to Holyoke.

Again, the Holyoke tables show only the working days of the year, omitting Sundays; and the effect of storage and storage reservoirs on the streams is included, because what is really measured is what you get having those reservoirs and having the advantage of them.

In relation to the monthly data, I do not see how it could be expected that ordinary water-works data should be computed any oftener than monthly, and for ordinary water-works purposes I don't see why that isn't all that is needed. But it does not seem applicable for power purposes. Of course we have had to use it for power purposes all along, but it does not seem so practicable as daily or weekly observations on these larger streams.

And another thing: an average, even when calculated in the

way I have suggested, gives too large a result, yet the manufacturer, in diversion cases, naturally wants the whole three hundred and sixty-five days, Sundays and all, and, failing this, he is satisfied with figures which are averaged, perhaps monthly, or in order of magnitude.

Now, to apply the principle in question is simply going somewhat further in the right direction without any danger of getting too far, because you can't get beyond the fact that the shortest distance between two points is a straight line, and all these other things are more or less incorrect.

(*By letter*, November 30, 1907.) Regarding the idea of arranging stream flow data in order of magnitude of whole term instead of each year, MR. H. G. SCHOFIELD, civil engineer of Bridgeport Conn., writes as follows: "I have myself for several years used a formula which must produce practically the same results, but with this difference, that I have used the twenty-year run-off of the Connecticut River at Holyoke as observed in ten-day periods, beginning with the least flow for that time, regardless of the date, and following it up by successive periods of the same length of time."

TABLE No. 9.

Showing Run-off in Second-Feet per Square Mile of Watershed for Each Tenth Day, beginning with the Least Day's Discharge, Regardless of the Time of Occurrence.

As deduced by H. G. Schofield, C.E., Bridgeport, Conn., from the table of Connecticut River flows at Holyoke, Mass., by Clemens Herschel, C.E., published in Proceedings of the American Society of Civil Engineers, November, 1906, page 928.

Column 1. No. of Period.	Column 2. Run-off in 24 Hrs.	Column 3. Run-off per Sq. M. per Sec.	Column 4. Run-off. Average of Two Periods.	Column 5. Horse-power at 80% Efficiency.
1st	2 607	0.32	0.34	0.030909
2d	2 935	0.36	0.375	0.0340909
3d	3 175	0.39	0.408	0.0370909
4th	3 470	0.426	0.441	0.0400909
5th	3 710	0.455	0.471	0.0428181
6th	3 977	0.488	0.501	0.045554
7th	4 200	0.515	0.527	0.047909
8th	4 392	0.539	0.552	0.050181
9th	4 602	0.565	0.578	0.052545
10th	4 815	0.591	0.610	0.055454
11th	5 122	0.629	0.651	0.059181
12th	5 470	0.672	0.692	0.062909
13th	5 805	0.712	0.731	0.066454
14th	6 120	0.751	0.769	0.069909
15th	6 425	0.788	0.807	0.073363
16th	6 727	0.826	0.839	0.076273
17th	7 135	0.851	0.889	0.080818
18th	7 557	0.928	0.957	0.087000
19th	8 037	0.987	1.017	0.092454
20th	8 537	1.048	1.082	0.098363
21st	9 085	1.115	1.150	0.104542
22d	9 652	1.185	1.225	0.111363
23d	10 312	1.266	1.301	0.118273
24th	11 042	1.356	1.397	0.12700
25th	11 710	1.438	1.483	0.134828
26th	12 452	1.529	1.584	0.14400
27th	13 352	1.639	1.708	0·155273
28th	14 470	1.777	1.869	0.16990
29th	15 982	1.962	2.046	0.18600
30th	17 355	2.131	2.261	0.20553
31st	19 487	2.392	2.524	0.22945
32d	21 635	2.656	2.834	0.25763
33d	24 532	3.012	3.255	0.295909
34th	28 487	3.498	3.972	0.36109
35th	36 217	4.447	5.097	0.46336
36th	46 817	5.748	7.233	0.65754
37th	71 000	8.718		

Column 1 shows ten-day periods arranged in order of magnitude.
Column 2 shows the average run-off for twenty years.
Column 3 shows average run-off per square mile per second.
Column 4 shows average run-off for each pair of periods.
Column 5 shows horse-power at 80 per cent. efficiency that may be derived from one square mile on a fall of one foot for a twenty-four-hour day. The horse-power in any given case may be obtained by multiplying the averages of column 5 by the fall in feet and this product by the number of square miles of watershed.

If a ten-hour day be required, multiply the above result by two and four tenths (2.4).

A PECULIAR LEAK IN A MAIN PIPE.

BY ROBERT C. P. COGGESHALL, SUPERINTENDENT NEW BEDFORD WATER WORKS.

[Presented December 11, 1907.]

MR. COGGESHALL. Mr. President, I hardly know how to begin, but as we had an episode in our town recently which was certainly peculiar, and as a number of inquiries have been made to-day by those who had read of the occurrence in the daily papers, I told the president that I would briefly describe the facts in the case.

The 24th of November, Sunday, was a stormy day. The storm increased in intensity until well into the night, and the following morning it was clear. The New Haven Railroad at the present time is engaged in abolishing grade crossings through our city. About all of the streets which cross this work are now in a demoralized condition. There has been an everlasting amount of work done in the transforming of gas pipes, water pipes, electric light cables, and street-car tracks to the new level. Any one who is familiar with New Bedford will know the location of the Wamsutta Mills, which are seen on the left as you enter the town. At this point, known as Acushnet Avenue and Wamsutta Street, the railroad tracks are to cross overhead in a diagonal way. The water pipes and the gas pipes have recently been lowered to the new grade, nearly four feet below their former level.

About nine o'clock on this Sunday morning a leak was reported on the surface of the street at this crossing. The employees of the water works and of the gas company were called, and it developed that the water was issuing from a gas pipe; that there had been a break in the gas main. It was puzzling to know from whence the water came. As far as we knew, there was no connection between the water pipes and the gas pipes, and yet the water was flowing from the gas pipe in pretty large quantities. There was a possibility that a connection had established itself with a pipe belonging to the railroad company, through which they supplied themselves with

water from a source some three miles away, but that did not seem probable. A few years previous the gas company had received water in its pipes from a brook north of this location; and at this time they had recently been laying pipes beneath a couple of other brooks. Excavations were made at those places and their pipe found intact.

All this consumed the time until the beginning of the afternoon. About two o'clock in the afternoon an employee of the gas company, coming through another street fully half a mile distant from the location where water was issuing on Wamsutta Street, noticed that water was coming pretty vigorously from a drip. He went to examine it. At the same time his attention was called to a murmuring noise in the hydrant close at hand. Our employees were again notified and worked in connection with the gas company employees in making an excavation. As there was no surface indication of a leak, there was no certainty as to the proper place to excavate.

At this point the water main, 16 inches in diameter, is upon the westerly side of the street; the gas pipe, 6 inches in diameter, is located on the easterly side. A 4-inch branch from the water main runs at right angles across the top of the gas main to supply the hydrant where the noise was heard. A large section of the water piping was shut off, gradually locating the leak near to the hydrant. We then assumed that it must be near the point where the hydrant branch crossed over the gas main. A trench was then opened to the bottom of the gas pipe, which was fully a foot below the water pipe, and this trench continued on toward the point of intersection, and it was not until it was opened within one foot of that intersection that water appeared from the leak, although you could hear it. When the excavation was completed the water and gas pipe were found to lie together as shown in this photograph, (Plate I, Fig 1.) The water pipe was the top pipe, and there was about half an inch of space between that and the lower or gas pipe. So closely had something made a connection between these two pipes that very little water appeared in the excavation. It was practically as if a nipple had been inserted connecting the two pipes. After punching and probing, the water appeared and immediately filled the trench. I

FIG. 1. GAS AND WATER PIPES IN POSITIONS IN WHICH THEY LAY IN THE GROUND.

FIG. 2. HOLES IN WATER AND GAS PIPES.

wish the composition which formed this connection had been saved for our later examination, but it was all lost. The water having been shut off and the trench bailed out, the gas issued forth so strongly that all work had to be abandoned that night.

The next morning the work of repair was made. Representatives from the gas and electric light company, which are under one management, the electric railroad company, and the water department were on hand. Tests for currents were made. At that time the current was plus to the gas main, less than a volt. A volt was the maximum; about half a volt was nearer the average. The maximum amperage was 0.6, 0.4 perhaps being the average. [These figures were verified by Mr. Wm. E. Foss, who visited the location a few days later.] Later in the day the superintendent of the electric railroad caused the entire current of his system to be shut off for a few moments, and the instruments indicated a zero reading, returning to readings given above when the current was resumed. This indicated pretty conclusively that the current under measurement at that time was due to the railroad power. The superintendent of the railroad made the statement on public print upon that day that probably they were the sinners. When the pipes were taken out it was seen that holes of about the same size had been bored through both pipes. These were about $1\frac{1}{2} \times 1\frac{1}{4}$ inches in size upon the inside edge of both pipes and flaring in both cases to the outside edge of pipe. These holes have the appearance of having been melted out quickly; several pits in the iron around these holes have the appearance of having been melted. The iron in both castings is excellent and there is a complete absence of that graphite-like softness which is an indication of gradual electrolysis. It would seem that the damage must have been caused by a current of much more intensity than that which was observed as stated above.

At the present time I can offer no solution of the cause. If it was due to what is known as electrolysis, it would seem as if only one pipe would have been damaged, that is, the pipe from which the current flows. The question of reversal of current has been suggested, but there is an absence of the graphite-like formation which under such a condition should be present. A short circuit is more probable, but we have not been informed that there is other

evidence of such an occurrence. It has been suggested that changes in bonding and wiring incidental to the grade-crossing work was responsible for the cause of this incident.

The gas mains were filled with water to such an extent that the whole northerly part of the city was completely deprived of gas for several days. Over thirteen hundred meters were damaged, beside other damages caused by water and explosions. All through this section, when people tried to turn on gas, they would obtain a little jet of water. At the present time the problem is unsolved, and I don't know that I can say anything further.

Mr. George A. Caldwell. May I ask one question, Mr. Coggeshall? Possibly it may be of interest. Is it not a fact that the water came from the gas burners in the houses at a higher elevation than that of the main line of gas pipe which was broken?

Mr. Coggeshall. Oh, yes, a good deal higher; some 15 or 20 feet higher.

Mr. Caldwell. I happened to be down there at New Bedford and I went into the matter very thoroughly with both the gas company and Mr. Coggeshall, and that is something which appealed to me as a very peculiar state of affairs, — that the water should come out through the gas fixtures at a higher level than the gas main on the street; and yet they were not troubled with back pressure of water in the gas mains for only about half a mile, I will say, from the break, that is, towards the gas works.

Mr. Coggeshall. I think possibly that may be explained by the fact that this joint which Nature made was almost a tight joint, and the water pressure at that point is some 75 to 80 pounds and it was probably due to the water pressure, because the connection was almost tight.

Mr. Caldwell. In that case, why didn't they have a back pressure of water in the gas main, which was only carrying a pressure of about 3 ounces?

Mr. Coggeshall. I don't know.

PROCEEDINGS.

November Meeting.

Hotel Brunswick,
Boston, November 13, 1907.

The November meeting of the Association was held at the Hotel Brunswick, Boston, at 2 p.m., on Wednesday, November 13, 1907.

President John C. Whitney presided, and the following members and guests were in attendance:

Members.

S. A. Agnew, C. H. Baldwin, L. M. Bancroft, H. K. Barrows, J. E. Beals, George Bowers, E. C. Brooks, George Cassell, C. E. Chandler, J. C. Chase, C. E. Child, J. H. Child, W. F. Codd, R. C. P. Coggeshall, J. W. Crawford, E. D. Eldredge, J. N. Ferguson, J. H. Flynn, F. F. Forbes, F. L. Fuller, J. C. Gilbert, A. S. Glover, R. A. Hale, F. E. Hall, J. O. Hall, J. C. Hammond, Jr., H. G. Holden, E. W. Kent, Willard Kent, G. A. King, F. A. McInnes, Hugh McLean, N. A. McMillen, D. E. Makepiece, A. E. Martin, W. E. Maybury, John Mayo, F. E. Merrill, H. A. Miller, C. A. Mixer, William Naylor, G. A. Nelson, O. E. Parks, E. M. Peck, H. E. Royce, H. W. Sanderson, E. M. Shedd, C. W. Sherman, G. A. Stacy, J. T. Stevens, W. F. Sullivan, H. L. Thomas, R. J. Thomas, W. H. Thomas, C. A. Townsend, D. N. Tower, W. H. Vaughn, C. K. Walker, R. S. Weston, J. C. Whitney, G. E. Wilde, F. B. Wilkins, G. E. Winslow. — 63.

Associates.

Anderson Coupling Co., by Charles E. Pratt; Ashton Valve Co., by C. W. Houghton; Harold L. Bond Co., by Harold L. Bond; Builders Iron Foundry, by F. N. Connet; Chapman Valve Mfg. Co., by Edward F. Hughes; Hersey Mfg. Co., by Albert S. Glover and W. A. Hersey; International Steam Pump Co., by Sam'l Harrison; Lead Lined Iron Pipe Co., by Thomas E. Dwyer; Ludlow Valve Mfg. Co., by H. F. Gould; H. Mueller Mfg. Co., by George A. Caldwell; National Meter Co., by Charles H. Baldwin, J. G. Lufkin and H. L. Weston; Neptune Meter Co., by Fred A. Smith and H. H. Kinsey; Pittsburg Meter Co., by F. L. Northrop; Rensselaer Mfg. Co., by Fred S. Bates; A. P. Smith Mfg. Co., by F. N. Whitcomb; Union Water Meter Co., by Frank E. Hall; Water Works Equipment Co., by W. H. Van Winkle. — 21.

GUESTS.

Kendall Pollard, Swampscott, Mass.; P. R. Sanders, Concord, N. H.; E. T. Harvell, Water Commissioner, Rockland, Mass.; C. N. Oakes, City Clerk, Westfield, Mass.; Amos H. Eaton, Chairman Water Commissioners, Middleboro, Mass.; Fred M. Hutchinson, Somerville, Mass.; Charles E. Dewey, Westfield, Mass.; John P. McCarthy, Member of Water Board, Lawrence, Mass., and Robert E. Newcomb, Holyoke, Mass. — 9.

[Names counted twice — 4.]

The Secretary read applications for membership from the following persons:

Harold T. Murphy, civil engineer, Springfield, Mass.; Charles E. Warren, trustee of Kennebec Water District, Waterville, Me.; G. L. Learned, trustee of Kennebec Water District, Waterville, Me.; Percy R. Sanders, superintendent of Concord Water Works, Concord, N. H.; Joseph M. Brown, chairman of water committee, East Orange, N. J., all of whom had been recommended for election by the Executive Committee.

On motion the Secretary was authorized to cast a ballot for the Association in favor of the applicants, which he did, and they were declared elected to membership.

The Secretary read a communication from the secretary of the National Municipal League, as follows:

NATIONAL MUNICIPAL LEAGUE.

PHILADELPHIA, November 6, 1907.

To the Members of the New England Water Works Association, — We take pleasure in extending to you a cordial invitation to attend an annual meeting of the National Municipal League, which will be held in conjunction with the American Civic Association, at Providence, November 19–22.

We enclose a program showing in detail the subjects that are to be considered at the meetings of these two bodies, and we especially call your attention to the joint session to be held on Friday morning, November 22, at which time the subject of "Municipal Health and Sanitation" will be considered.

Hoping that you will be able to attend these sessions, I am,

Very truly yours,

CLINTON ROGERS WOODRUFF,
Secretary.

On motion of Mr. R. C. P. Coggeshall, duly seconded, the Secretary of the Association was instructed to acknowledge the re-

ceipt of the invitation of the National Municipal League, and to thank the secretary for sending it.

Mr. Charles W. Sherman. Mr. President, those of us who were at Springfield will remember that a committee was appointed at the convention which I believe is going to do a very valuable work for the Association, a committee to compile data on damages from water diversion cases. It has recently occurred to me that a similar committee to compile data with reference to water works valuation cases would do work of equal value to the Association, and it would be a work in which perhaps a larger percentage of our members would have an active interest.

I, therefore, bring the matter before this meeting, and if it meets with favorable consideration, I will present a motion that the President appoint a committee of five to compile information relating to awards that have been made in water-works valuation cases.

It seems to be more and more common — at least in this part of the country — for municipalities to take possession of privately owned water works, and, so far as I have heard, in every such case there has been a court valuation of the works so taken, and the amount to be paid by the municipality has been decided by that award.

Very few of us see any information, or anything more than newspaper reports, of such cases, and it seems to me that there is a chance here for a committee to do a work of great value to the Association.

I would like an expression of opinion from some of the members present before I formally present that motion, if the President will allow it to come in that way; but if all of them see it as I do, I shall be glad to offer it.

The President. You have heard Mr. Sherman's remarks; is there anything to be said? We would like to have an expression of opinion from the members regarding the advisability of appointing a committee of this kind.

Mr. John C. Chase. That is a matter that has touched me in a tender spot twice within the last few months. If Mr. Sherman will put his motion, I will very heartily second it.

Mr. Sherman. In that case, Mr. President, I will formally offer the motion.

Mr. Charles A. Mixer. Mr. President, before the motion is really put, might it be made to include not only works that have been valued, but also works that shall be valued in the future?

Mr. Chase. Mr. President, I am afraid that would cut into the services of some distinguished experts who want a job. [Laughter.]

The President. I am afraid that our prophetic sense will not reach quite to that point.

(The motion, on being seconded, was put by the President, and declared to be a vote.*)

Mr. Robert E. Newcomb, M.E., Holyoke, Mass., read a paper entitled "Fire Hydrants." It was discussed by Messrs. G. A. Stacy, F. A. McInnes, E. C. Brooks, W. F. Sullivan, J. H. Flynn, R. J. Thomas, F. S. Bates, E. F. Hughes, F. L. Fuller, John C. Chase, Hugh McLean, and George Cassell.

Mr. George A. Stacy offered the following vote: Moved, that the President be authorized to appoint a committee of five to prepare a standard specification for fire hydrants.

The motion was seconded and carried.†

Mr. Charles E. Chandler, C.E., Norwich, Conn., read a paper entitled "Stream Flow Data, from a Water-Power Standpoint." It was discussed by Messrs. R. A. Hale, Charles A. Mixer, H. K. Barrows, Charles W. Sherman, and Mr. Chandler.

The meeting then adjourned.

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* The President subsequently appointed the following committee: Messrs. Allen Hazen, Desmond FitzGerald, Charles A. Allen, John C. Chase, and Francis W. Dean.

† The President subsequently appointed the following committee: H. O. Lacount, George A. Stacy, Frank A. McInnes, Frederick W. Gow, and William F. Sullivan.

PROCEEDINGS.

DECEMBER MEETING.

HOTEL BRUNSWICK,
BOSTON, December 11, 1907.

The December meeting of the Association was held at the Hotel Brunswick, Boston, at 2 P.M., Wednesday, December 11, 1907.

President John C. Whitney presided, and the following members and guests were present:

MEMBERS.

S. A. Agnew, C. H. Baldwin, L. M. Bancroft, J. E. Beals, J. W. Blackmer, C. A. Bogardus, E. C. Brooks, George Cassell, J. C. Chase, C. E. Childs, F. L. Clapp, R. C. P. Coggeshall, M. F. Collins, W. R. Conard, C. H. Eglee, C. R. Felton, A. N. French, D. H. Gilderson, A. S. Glover, R. A. Hale, F. E. Hall, T. G. Hazard, Jr., B. B. Hodgman, J. L. Howard, E. W. Kent, Willard Kent, F. C. Kimball, G. A. King, T. H. McKenzie, Thomas McKenzie, N. A. McMillen, D. E. Makepeace, A. E. Martin, John Mayo, F. E. Martin, William Naylor, F. L. Northrop, E. W. Shedd, C. W. Sherman, H. W. Spooner, W. F. Sullivan, R. J. Thomas, W. H. Thomas, J. A. Tilden, C. A. Townsend, W. H. Vaughn, J. C. Whitney, G. E. Winslow. — 48.

ASSOCIATES.

Anderson Coupling Co., by F. A. Leavitt; Harold L. Bond Co., by Harold L. Bond; Chapman Valve Mfg. Co., by Edw. F. Hughes; Eagle Oil & Supply Co., by J. L. Hamilton; Hersey Mfg. Co., by Albert S. Glover, J. A. Tilden, W. A. Hersey; International Steam Pump Co., by Sam'l Harrison; Lead Lined Iron Pipe Co., by Thomas E. Dwyer; Ludlow Valve Mfg. Co., by H. F. Gould; H. Mueller Mfg. Co., by George A. Caldwell; National Meter Co., by C. H. Baldwin, J. G. Lufkin, and H. L. Weston; National Water Main Cleaning Co., by Burt B. Hodgman; Neptune Meter Co., by H. H. Kinsey; Pittsburg Meter Co., by F. L. Northrop; Rensselaer Mfg. Co., by C. L. Brown; A. P. Smith Mfg. Co., by F. N. Whitcomb; Thomson Meter Co., by E. W. Shedd; Union Water Meter Co., by Edw. P. King and F. E. Hall; United States Cast Iron Pipe & Foundry Co., by Frank W. Nevins; Water Works Equipment Co., by W. H. Van Winkle. — 24.

GUESTS.

James G. Hill, water commissioner, Lowell, Mass.; Baron DeWill, Paris, France; E. T. Harvell, water commissioner, Rockland, Mass.; J. F. Moore, Pascoag, R. I.; S. B. Palmer and Z. R. Robbins, Norwich, Conn.; A. E. Blackmer, Plymouth, Mass.; Arthur F. Ballou, superintendent, Woonsocket, R.

I.; Charles G. Roberts, water commissioner, Chelsea, Mass.; Charles F. Glavin, of Chas. Millar & Sons Co., Utica, N. Y.; L. H. Caufel, Boston, Mass., and F. M. Hutchinson, Somerville, Mass. — 12.

[Names counted twice — 7.]

The Secretary announced that application for membership had been received from the following-named persons, and had been properly endorsed and recommended by the Executive Committee:

Active. — J. S. Thornton, Sonora, Cal., general manager of Tuolumne County Water and Electric Power Co., Sonora, Cal.; Arthur F. Ballou, superintendent Water Department, Woonsocket, R. I.; Harry S. R. McCurdy, Brown's Station, N. Y., with New York Board of Water Supply; John F. Morse, Pascoag, N. J., with Pascoag Water Co.

Associate. — Charles Millar & Sons Co., Utica, N. Y., manufacturers of cast-iron water and gas pipe.

On motion of Mr. Chase, the Secretary was instructed to cast one ballot in favor of the candidates named, and, he having done so, they were declared by the President duly elected members of the Association.

Mr. Charles H. Eglee, hydraulic engineer, Boston, was called upon as the first speaker of the afternoon. His subject was, "Hollow Concrete-Steel Dams." At the conclusion of his remarks Mr. Eglee answered questions asked by Mr. R. C. P. Coggeshall, Mr. Wm. F. Sullivan, Mr. T. H. McKenzie, Mr. D. E. Makepeace, and Mr. Richard A. Hale.

Mr. Coggeshall told of a rather peculiar experience in New Bedford recently, where Nature had apparently in some mysterious way established a connection between a gas main and a water main which were about half an inch apart, and the gas pipes in a large section of the city had been filled with water.

In response to an inquiry by the President as to a good method of protecting water pipes over bridges from frost, Mr. Coggeshall and Mr. Frank L. Fuller advised boxing and an air space.

Mr. H. W. Spooner, engineer of the Gloucester Water Works, showed some excellent lantern slides of views on Cape Ann and at Magnolia and of mackerel fishing operations.

Adjourned.

EXECUTIVE COMMITTEE.

TREMONT TEMPLE, BOSTON, MASS.,
Wednesday, November 13, 1907, 11.30 A.M.

Present: President John C. Whitney, and L. M. Bancroft, George A. King, Robert J. Thomas, Charles W. Sherman, and Willard Kent.

The following applications, five in number, were received and recommended for membership in the Association:

Harold T. Murphy, Springfield, Mass.; Charles E. Warren, Waterville, Me.; G. L. Learned, Waterville, Me.; Percy R. Sanders, Concord, N. H.; Joseph M. Brown, East Orange, N. J.

Voted: That "The Liberty Trust Company" be and hereby is approved as a place of deposit for a portion of the funds of this Association.

Voted: That the Treasurer, President, and Editor be a committee on the investment of the funds of the Association, to investigate and report at the next meeting of the Executive Committee.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

TREMONT TEMPLE, BOSTON, MASS.,
December 11, 1907.

Present: Vice-President George A. King, presiding; Charles W. Sherman, Robert J. Thomas, L. M. Bancroft, A. E. Martin, Willard Kent.

The following applications were received and recommended for membership:

Members: John F. Moore, Pascoag, R. I.; Harry S. R. McCurdy, Brown's Station, N. Y.; Arthur F. Ballou., Woonsocket, R. I.; J. S. Thornton, Sonora, Cal.

Associate: Charles Miller & Son Co., manufacturers of cast-iron water and gas pipe, Utica, N. Y.

The Secretary was instructed to investigate the advisibility of having the expense of room for the monthly meetings charged to the Association, if a corresponding reduction can be made in the price of the dinner tickets.

The Treasurer reported progress of the work of the Committee on Investment.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

OBITUARY.

Arthur J. L. Loretz, mechanical engineer, of 397 Ninth Street, Brooklyn, N. Y., died May 27, in California. He was born in the Province of Alsace, then France, and was the youngest son of the late Prof. J. B. Loretz, of Brooklyn. He was intimately associated with the pumping engine trade for years, was an inventor, patented the national steam pumps and pumping engines, was awarded three medals in 1875–6 for these pumps by the American Institute of New York, New Jersey, and Philadelphia, and numerous diplomas. Has been consulting engineer for large manufacturing plants. Mr. Loretz became a member of the New England Water Works Association on December 9, 1896.

TRADE PUBLICATIONS.

Allis-Chalmers Company, Pumping Engine Department, Bulletin No. 1610. August, 1907.

Allis-Chalmers Vertical Tandem-Compound Screw Pumping Engine, built for the Kinnickinnic Flushing Tunnel, Milwaukee, Wis.

This bulletin describes the screw pumping engine, with a capacity of 323,-000 000 gallons per day, lifted 3½ feet, by which Lake Michigan water is pumped into the Kinnickinnic River for flushing purposes.

JOURNAL

OF THE

New England Water Works Association.

VOLUME XXII.

1908.

PUBLISHED BY

THE NEW ENGLAND WATER WORKS ASSOCIATION,
715 Tremont Temple, Boston, Mass.

The Fort Hill Press
SAMUEL USHER
176 TO 184 HIGH STREET
BOSTON, MASS.

INDEX.

ALFRED E. MARTIN.

President New England Water Works Association.

1908.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XXII. March, 1908. No. 1.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

EXPERIENCE WITH A PRODUCER GAS PLANT.

BY HARRY L. THOMAS, ASSISTANT SUPERINTENDENT, HINGHAM WATER COMPANY, HINGHAM, MASS.

[*Read January 8, 1908.*]

In presenting this paper I do so with a considerable degree of timidity when I realize that the duty falls upon me to introduce to this Association the application of producer gas to the needs of our business as water-works superintendents and officials, and it would undoubtedly have been wiser had a more general treatise been first presented by an eminent authority, to be followed by the experience papers of us " small fry." But I wish in no way to question the wisdom or judgment of our worthy secretary, by whose urgent request this matter is presented, and the announcement borne upon the notice for this meeting, " Experience with a Producer Gas Plant," will surely lead you gentlemen to anticipate nothing but an account of the most ordinary everyday experiences which have come to us in the management of our new station and its equipment. Whatever is here presented is but a meager part of our experience. There is much that can better be told to an attentive ear than recorded in this paper; therefore should I fail to make clear the descriptions, and this treatise fall short of your expectations, rest assured that at any time you feel inclined to pay us a visit, by dropping us a line at the office in advance, my time and an automobile will very gladly be placed at the disposal of any of you gentlemen.

Our plant was installed in the spring of 1906, the test being made in May of that year. It is located at Fulling Mill Pond, one of our

sources of supply, and during the summer season, when the greatest demand is made on the system, is used to pump water to the receiving basin at the Weir River Station through 20 000 feet of 14-, 12-, and 10-inch pipe. From there the water is again pumped into the distributing system by a Deane steam pump. Lest surprise be felt at the handling of the water twice over, let me explain that it is contemplated to, in the near future, dispense with our steam plant, and by increasing the number of units of the producer plant, and providing suitable mains, do all our pumping at Fulling Mill Pond.

The entire equipment, producer, engine, and pump, was furnished and installed under contract by the Olds Gas Power Company, of Lansing, Mich., and consists of a Pintsch system suction gas producer of size to furnish sufficient gas to generate 70 horsepower; a 65 horse-power, single cylinder, Olds heavy duty, type K gas engine; a 13 × 12 Smith-Vaile single-acting, outside packed plunger, triplex pump; and a compressed air starting outfit. The foundations, furnished by the water company, are of concrete, and the whole is housed in a wooden frame building 30 × 36 feet, situated 50 feet from a collecting well 40 feet in diameter and 20 feet deep, from which the water is pumped, and so placed that the center line of the pump is parallel to, and 15 feet from, the 14-inch pipe leading from the well. The building, which is temporary, built to accommodate the present unit until such time as others are added, is very plain, as the photograph will show, and is divided into two rooms by a tight partition running from floor to roof, separating the engine and pump from the producer, made necessary by the unavoidable dust and ashes consequent upon cleaning the fire in the generator.

The photographs which are reproduced in Plates I and II show what the machines look like, but can hardly give a definite idea of their relative arrangement, and in order to make this clear we will consider it for a moment by beginning in the producer room. This is 30 × 13 feet, the floor being for the most part of brick, as in cleaning the fire some live coals are very apt to roll out. First stands the generator in which the gas is made. It is cylindrical in form, 3 feet 6 inches diameter by 7 feet 6 inches high, inside measures, and is supported by three iron legs which raise

FIG. 1. FULLING MILL POND PUMPING STATION, HINGHAM WATER CO.

FIG. 2. CHARGING FLOOR, SHOWING CHARGING HOPPER OF GENERATOR.

it 2 feet from the floor. It is lined with courses of properly molded fire brick 8 inches in thickness, the joints being made up with fire clay. Between the shell and this lining is a space of 1 inch, and after each course of brick was laid this space was very carefully filled with mineral wool to avoid the possibility of any air working in and either affecting the composition of the gas or creating an air pocket to retard the flow of the same. The bottom course of brick rests upon the frame supporting the shaking grate, which is funnel-shaped, provided with a draw center. On either side of the generator are two doors, one above the other, the upper one opening at the top of the grate, allowing space for cleaning and poking the fire, the lower one giving opportunity for shaking and drawing the grate when necessary to work out an accumulation of clinker. From the bottom of the generator a tube 10 inches in diameter leads down to a water-sealed ash pit, thus enabling the removal of ashes without admitting an undue amount of air into the fire. Such is the nature of producer gas that the proper amount of air admitted to the fire is of vital importance, and unless great care is exercised, perplexing results are inevitable. In operation we have sometimes found that under certain conditions of fire and fuel the opening of the fire or grate doors for more than half a minute at a time was impossible without producing trouble.

The generator is filled and fed from the top, for this purpose a cast-iron charging hopper being provided which will hold 85 pounds of coal. When charging becomes necessary the hopper is filled, its cover closed and fastened, and it is then swung around until it comes over a hole in the center of the top, when the coal simply runs down into the fire; the hopper is then swung back ready to receive another charge. By means of a ground joint this hopper is self-sealed, again guarding against improper admission of air.

At one side of the generator is situated an apparatus for injecting steam and air into the fire. These are both admitted through the same pipe into the ash tube previously referred to, and the present apparatus, which has replaced that originally attached, is most satisfactory in its working. It is provided with proper valves to regulate both air and steam.

Standing beside the generator is the vaporizer, cast iron, of the independent type, having a water-sealed cleaning pot and a relief chimney to the atmosphere. In this is generated the steam for use in the fire. It is cylindrical in form and built in three sections bolted together, the bottom part providing the seal for the generator as well as a cleaning pot for the vaporizer itself. The middle section contains a number of 1-inch tubes surrounded by water, and during operation the hot gas passing down through these tubes generates the steam, which passes to the injector before alluded to through a $1\frac{1}{2}$-inch pipe leading out from the upper section, which is provided with a water jacket to which is attached a gage glass and overflow pipe. The gas port from the generator comes into this upper section, and is reached for cleaning by removing the flat top of the vaporizer, which also gives access to the tubes when it becomes necessary to brush them. Connected with the bottom section is the relief or chimney pipe.

Next stands the scrubber, provided with a grate placed about 18 inches from the bottom, and from this to the filling door near the top this is filled with clean egg size coke. Through its top projects a $1\frac{1}{4}$-inch pipe, having on its end a perforated ball from which, during operation, a spray of water is constantly pouring. In this machine the gas gets its principal cleaning and is cooled by the water spray, more or less water being used as the temperature of the gas requires.

The next and last machine through which the gas passes is the cleaner or dry scrubber, which is fitted with two grates, one above the other, 8 inches apart, upon which are evenly distributed clean mill shavings to the depth of 3 inches, and to prevent these dropping through the grates, coarse mesh burlap is laid on. It is 4 feet 8 inches in diameter, so made that the whole top may be lifted to provide easy access for cleaning. In our plant we consider this machine plays a most important part in preparing the gas for the engine by removing any tar, carbon, or dirt which may pass along with the gas, thereby assuring cleaner valves, gas ports, and combustion chamber than could reasonably be expected without this cleaning; and great pains are taken that the filling of shavings shall at all times be evenly distributed and the layers of proper thickness. When at any time evidence of dirty gas is found, our first care is given to this machine.

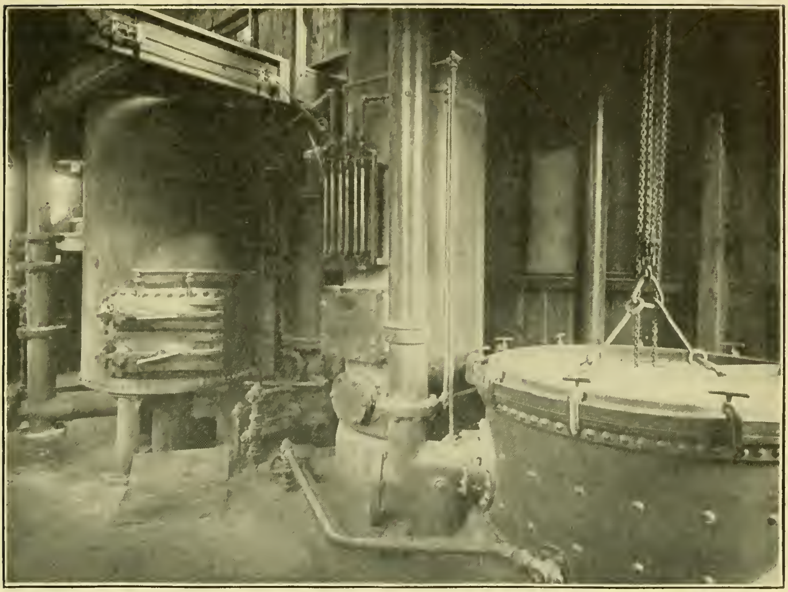


FIG. 1. PRODUCER ROOM, SHOWING GENERATOR, VAPORIZER, SCRUBBER, AND CLEANER.

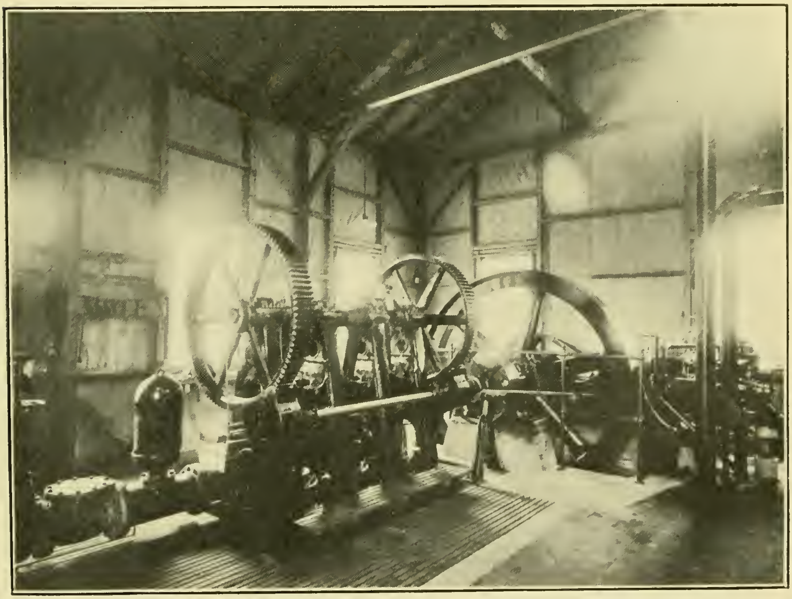


FIG. 2. ENGINE AND PUMP ROOM.

The four machines just described constitute what is termed the producer, from the fact that they all figure in the preparation of the gas. In the same room with these is the compressed air starting outfit, comprising a small compressor driven by a belt from a gasoline engine with the necessary storage tank. Belted to this same engine is the blower used when starting the fire in the generator.

The engine, four cycle, single cylinder, is very compactly built, measuring approximately 11 feet $\times$ 4 feet 3 inches; the top of the governor, which is the highest point, being 5 feet from the floor, and the fly wheel, 9 feet in diameter with a 12-inch face, weighing 8 000 pounds. The crank shaft is 6 inches in diameter in bearings, the main and outboard bearings being of the ring oiler type with babbitt-lined boxes. The connecting rod is a solid steel forging, fitted at the crank end with a babbitted box and at the wrist pin end with a phosphor bronze box. When originally installed, the crank pin was oiled by a centrifugal oil ring fastened to the crank cheek and fed from a sight feed oiler, but after numerous experiences with a hot crank pin, melted box linings, etc., this was replaced by a wiper, and a great source of trouble and worry removed. For lubricating the wrist pin, piston, and exhaust valve stem, a sight feed pressure pump attached to the engine bed and operated by the side shaft is used. The speed is regulated by a Jahn's governor working on the common air and gas valve, and ignition is furnished by a Bosch magneto.

The pump, which is of the triplex geared type, is connected with the engine by a friction clutch and, when running at rated speed of forty-two revolutions per minute, will deliver one and one quarter million gallons in twenty-four hours, this being the duty which will be required of this unit when the contemplated plant is complete.

I shall assume that for the purposes of this paper the foregoing descriptions are sufficient, but if they prove not to be, perhaps more can be brought out in any discussion which may follow, and it may be well to now consider briefly the matter of generating the gas and its progress to the engine.

A wood fire is first built, and when this is well going, anthracite pea coal is put in until the generator is filled to its full capacity, 1 260 pounds. As soon as practicable the blower is applied, but

we are always careful not to blow too hard with a fresh fire, as it is an easy matter to overheat the grate, particularly if coke is used for a foundation. In our practice we never start the plant with an absolutely fresh fire, — not that it cannot be done if necessary, but we prefer to have a cooler fire to work with, which we get by building it up slowly until in proper condition and then allowing it to stand over night. During the building up of the fire, and until the proper quality of gas is obtained, the chimney pipe is kept wide open to provide draft and an outlet for waste gases, and under ordinary conditions an hour's blowing is necessary.

In order to test the gas a $\frac{3}{8}$-inch cock is tapped into the lower section of the vaporizer above the water seal, and when the gas from this will burn with a firm, full blue flame having a yellow tip, we consider we have it in sufficient quantity and proper quality to be blown over to the engine. If, however, when testing, we get an all-yellow flame, experience prompts us to let that gas go up chimney, as it is so hot that it cannot be properly cooled before reaching the engine; and should we start with it, pre-ignition would inevitably result, attended by uncomfortable circumstances.

Having obtained a good test of gas at the generator, we are now ready to blow over. Tapped into the gas main near the engine is a $1\frac{1}{2}$-inch pipe which is fitted with a plug stop and running out to the atmosphere; and near this pipe is placed a second test cock. With the blower still running, this pipe is opened, the water seal emptied, and the chimney pipe closed. This allows all the gas to be carried through the various machines to the engine, with the relief at the engine instead of at the generator as before. When good gas comes from this cock the water seal at the generator is refilled, chimney pipe opened, and a few minutes more of blowing, to be sure that the generator is well filled and the fire hot, makes us ready to start.

Right here it may be of interest to follow the course of gas to the engine. It leaves the generator at the top, entering the vaporizer at its top and, passing down through the tubes, passes out at the bottom. As has already been said, in passing through the tubes it generates the steam, which under good conditions

takes about thirty minutes. Then entering the scrubber at the bottom, it is drawn up through the coke, where it is met by the spray of water before mentioned, and, passing out through the port at the top, is drawn through the gas main to the top of the cleaner. Here it passes through the shavings and escapes through the bottom to the engine. In its entire course it is drawn along by the suction of the engine piston, and it is, therefore, quite impossible that any gas can escape; and it also becomes imperative, for the same reason, that no leaky joint or fixture shall admit of any air being drawn in at other than legitimate places.

Having blown the generator hot, as we term it, with a view to starting, the water seal is again emptied, chimney pipe closed, one of the fire doors opened just a little to be sure that some vent for gas confined in the generator is provided, and the throttle valve in the gas main at the engine opened. The engine is then started by compressed air, and under favorable conditions, after three or four revolutions, we get explosions in the combustion chamber; the air is shut off, the lever which controls timing of ignition properly adjusted, and our engine is fairly under way. But alas! one very important detail has been omitted from the rather confusing sequence of maneuvers, and I ask you kindly to assume that the wire connecting magneto and igniter has been put in place, with the humble assurance that not only was it omitted from the proper place in this narrative but, to the inexpressible chagrin of all concerned, it has sometimes been omitted in actual practice. (This was in the early days.) The generator door is now tightly closed, the air feed pipe from atmosphere opened, blower pipe shut off, the clutch pulley thrown in, and the several oil and bearing cups adjusted for the day. After the engine has been fairly under way the water is turned on for the scrubber spray, the proper feeding of which is very essential.

As closely as I can transcribe them, these are the steps taken in starting up the engine and pump, and the next topic might naturally relate to our experiences, sublime, ridiculous, and exasperating, and which, in justice to the subject as announced, perhaps should have formed the sole and important body of this paper. I trust my descriptions have in no great degree been tiresome to you, for I felt that a certain amount were necessary that you might

better follow my thought; and that those unaccustomed to such installations could gain a faint idea of the make-up of this particular system of gas producer.

The proposal offered by the firm that installed our plant includes among others the following clause:

"We are to furnish a representative to operate the plant for thirty days after the installation, whose duty it will be to properly instruct such representatives as you may appoint in the duties involved in the successful operation of both producer and engine."

What would have happened had not such instruction been placed at our disposal can, I assure you, be better imagined than recorded, for, in spite of the persistent and patient efforts of the aforesaid representative of the party of the first part to imprint upon the memory wise and serious truths, after the expiration of the aforesaid thirty days the aforesaid representatives of the party of the second part were promptly and on divers occasions "stuck for fair." Whereupon aforesaid representatives of the party of the second part did loudly and wildly utter such strange and unseemly language as would be unbecoming in this transcript. I am not breaking confidences when I relate any of our experiences, and lest any of you may be apprehensive, let me say that we have, for our purpose, an excellent plant, doing good continuous service and, under the charge of two reliable engineers, keeping well up to the standard of economy and efficiency for which such claims were made.

A very early difficulty encountered was the proper handling of the fire, and many times, after looking everywhere else for the source of the trouble, we were brought face to face with poor conditions at the generator, with gas of insufficient quantity and inferior quality. The experience of both operators as steam engineers was of no material benefit, and frequently the stoking bar was hung up with a bang, accompanied by the remark, "I thought I knew how to run a fire, but, after all, I guess I don't." They did understand running a steam boiler, but this was an entirely new process of firing, to be mastered only by failures and hard knocks, and we pride ourselves that now we have, in great measure, conquered the difficulty, and while a change in the grade of coal may occasionally cause slight inconvenience, we are able to cope

with it in an understanding manner and without disastrous results.

Under favorable conditions of fuel, the body of incandescent coal is about 18 or 20 inches deep, and the gas, carbon monoxide, is generated by the proper combining of certain elements during the passage of air and steam through the fire. But the proper combining in the early days was an uncertain quantity, and the entry in the record book by our engineer, " Started engine 8 A.M., ran ten minutes, and then fainted," recalls vividly to my mind many a heart-rending scene which resembled the time when, in younger days, we got the swing well under way and then stood to " let the old cat die."

Now the conditions which led up to this entry were these: The fire had been blown as usual and gas of good quality had been tested at both cocks; but at the end of the ten minutes all the gas had been exhausted from the machines, and what was being generated was not sufficient to supply the wants of the engine. This lack of gas was due to the presence in the fire of a large amount of hard clinker, and the clinker had been caused by improper proportioning of steam and air under the grate. Had more steam been admitted, while possibly clinker might have been present, it would have been at least porous, and the choking of the flow of gas reduced.

Again, the air was furnishing the major quantity of oxygen consumed, and its other element, nitrogen, an inert gas, was present in sufficient volume to displace other gases necessary for combustion. The record states that several trials were made to start, with similar results, and further attempts were abandoned until the fire had been thoroughly overhauled, which was accomplished by slicing from the top through a poke hole provided for that purpose, and using great care that any clinker attached to the lining was broken off. Then from the fire doors, by the use of a hooked bar, these were withdrawn and the generator filled with fresh coal, after which the blower was applied and the usual course pursued. It may be best to say here that the clinker which did the mischief had been accumulating during the run on the previous day, thereby leaving us a dirty fire with which to start.

Equally perplexing results were experienced later in our oper-

ating, and I again refer to the engineer's record book and find there entered, " Fourth of July for five minutes; then ran nice for a few minutes. At 8.25 down and out." Gentlemen, the utter abandon which prompted this entry can only be appreciated by those who, while working in ignorance and struggling with inexperience, try to make themselves and others believe that at last they understand operating a producer gas plant, and the cause of this entry may naturally be spoken of now. Whereas in the previous case steam was lacking, the difficulty was now due to an over-abundance of it, together with a hot fire; and the highly explosive hydro-carbons, which were in excess, were taken over to the engine and very heavy explosions occurred, which could not only be heard, but plainly felt in the vibration of the combustion chamber end of the engine. At the particular time in question, pre-ignition also contributed to the general fuss, brought about by a dirty combustion chamber, and from the fact that the heavy charge was ignited in the chamber before the admission valve was wholly closed, the force of the explosion was felt way back to the cleaner, where the shavings were disturbed by the current passing in the opposite direction from that intended. The noise produced by these explosions was extremely loud, both in the gas main and exhaust pipe, and when it occurred, as it sometimes did, during a calm summer night, the neighbors a mile distant became alarmed lest our quiet old town had been attacked by a battery of twelve-pounders. The explosions would continue for three or four minutes in rapid succession, during which time we cudgeled our brains for a cause, and usually resulted, as recorded by the engineer, in stopping the engine.

By the aid of the representative of the party of the first part we soon came to understand that here again we must look to the generator for the seat of difficulty and cool the fire; at the same time reduce the steam. " But," we argued, " we were told that we must have steam to cool the fire, and in order to get that quickly for the purpose we must have a hot fire, and hot fire and steam give this result. What is to be done? " Well, the only thing that could be done just then was to cut off the steam and run chances that our fuel would not clinker badly until matters came to rights and we again had command of the situation. In

this case, also, ignorance allowed us to let the fire get beyond us and become so hot that steam in sufficient quantity to cool it did its own peculiar mischief. I am free to say that of all the " kinks " accompanying the plant, this one of proper firing is by far the most important, and one which no amount of instruction and reading, unless accompanied by experience, can make plain, very many details of fuel, fire, air, and steam under varying conditions having a direct bearing upon results.

To aid in selecting fuel, calorimeter tests were made, with the result that the sample first selected contained 13 150 British thermal units per pound of dry coal, and during the test of the plant and for some time after this gave good results. The second purchase was made after a sample was tested, showing 12 998 B. T. U. per pound of dry coal and 8.4 per cent. ash; but a radical change in the condition of the fire became apparent by its use, and despite our best efforts we could not keep it cool. Another new feature appeared in the shape of a very deep body of incandescent coal, and it seemed impossible to prevent the fire working up high in the generator. This was first noted when, after running the bar up into the fire, no fresh coal would follow down. The clinker removed was of an entirely different character; it came out in large patches like masses of soft rubber, finally accumulating, despite our efforts, in a solid mass at the top of the fire doors that would nearly support the entire body of fuel. Steam was being admitted, we knew, in maximum quantity for safety, and the engine, while it continued to run, was pulling for gas very hard. Against all reason and practice, in order to ease up this pull, the fire was poked from the top every half hour, and it was observed that the hole made by the poke bar remained open and that the blowing of excess steam from the safety valve also stopped. We were brought to conclude, therefore, that the fire was filled with this mass of peculiar soft clinker, and that when the bar was withdrawn chimneys of hot gas, which are most undesirable, were formed, and not only was the fire, by reason of the frequent pokings, burning high, but we were making hot gas and paving the way for more Fourth of July stunts, which soon spoke for themselves.

But luck comes to every one sometime, and while shut down for

an hour to clean valves and change igniters we noticed a heavy deposit resembling sulphur in appearance and odor, and the thought came to me that I had read that sulphur was a great enemy to a gas producer. Reference proved my memory correct, and here we had the explanation of our difficulty, for the sulphur, which usually occurs as iron sulphide, in melting had formed a base around which clinkers had formed in vast quantities, and any effort to prevent this would prove futile. The ultimate result was that the fire was drawn from the generator, and the coal for future running was purchased and still is purchased from a local dealer who furnishes us pea coal screened from the various bins on his wharf, which is proving excellent for our use. Coal with a high per cent. of ash can be used very nicely if the percentage of sulphur is low, but the foregoing experience easily proves what may happen if sulphur is present in excessive proportion.

Other experiences by which we have profited have come to us and are still coming: adjustments of admission and mixing valves; the best point for ignition under varying circumstances; proper amount of oil required to lubricate piston without overfeeding and consequent burning; regulation of water spray in scrubber; care of cleaner with a view to preventing any considerable amount of dirt or carbon being carried to the engine; methods by which "back fires" may be quickly and quietly stopped, if not prevented; and numerous others which it seems not necessary to detail, as they vary with us, as they would anywhere else with local conditions of plant and fuel. Those I have spoken of are, I am satisfied, very likely to fall to the lot of any one who, as we have, operates a producer gas plant without any previous experience, unless an abundance of good luck comes his way.

The results obtained from the plant are most satisfactory. Our longest continuous run to date was made from 5.15 A.M. November 24, to 1.50 A.M. December 4, 1907, 235¾ hours; the plant had been in operation since November 2 and the stop was made for the purpose of cleaning the mixing valve and changing igniters, which occupied two hours. This was not planned in any way as a record run; our engineer assures me that it was not absolutely necessary to stop when he did, but we had shortly before this been troubled with dirty gas, and we were curious to note what effect,

if any, had been produced by increasing the amount of shavings in the cleaner. Much to our satisfaction it had proved to be of great benefit. Our plant is now running 24 hours a day, and we are pumping $1\frac{1}{4}$ million gallons with a coal consumption of 1 100 pounds. The record for yesterday was 62 440 revolutions; the total head, including suction lift, was 108.4 feet; coal fired, 1 085 pounds. This gives a duty of 107.6 million foot pounds per one hundred pounds of coal. The cost of coal per ton was $4.67. The cost of coal per ton used at the steam plant is $5.50, so that in order to compare the efficiency of the two plants on a basis of dollars and cents, it would be necessary to add nearly eighteen per cent. to the duty of the gas plant, which will bring this duty up to 126.6 million. While no test has been made at the steam plant, my belief is that its duty will not exceed 40 million, so that fuel cost of pumping by steam is three times that of pumping by producer gas. During the test of the producer gas plant its duty per one hundred pounds of coal fired exceeded 135 million.

I desire to call your attention now, if I have not before, to the fact that we are pumping against but 110 feet total head, while the unit is designed to work against from 160 to 170 feet total head, which it did during the test above mentioned; also to say that while the engine is now running under a little more than half load, the duty would be materially increased were it running up to rated capacity.

And now, gentlemen, I feel that to say more in this paper may be needless. I reiterate what was said in the beginning, that much can betteı be told than written, and I renew what I assure you was a hearty and genuine invitation.

DISCUSSION.

Mr. E. H. Gowing.* Mr. President and gentlemen, my experience with this plant would not incline me to hold to the old-fashioned steam engine — for a small plant. It seems to me that the duty they are getting right along every day with a little over half load shows that the fuel cost of pumping water with a gas-producer plant is very much less than with a steam plant, — that

* Civil Engineer, Boston, Mass.

is, the kind of steam plants which we put in for a 1 000 000 gallon plant through New England.

If I were to put in another plant for myself for pumping water, or if I were to build a small electric power station, I should, I am sure, put in some kind of a producer gas plant. I know that neither Mr. Thomas or the officers of the Hingham Water Company would take that plant out and replace it by any such steam plant as is ordinarily put in for that purpose. Of course, if one had to install a 10 000 000 gallon plant or larger, one could get equally good results, equally high duty, from a steam plant, and perhaps might prefer to put in steam, that is, bearing the evils that we have, rather than flying to those we know not of. You will get the idea if I don't quote it just right. [Laughter.] I have had some experience with internal combustion motors for pumping water. We have two at Cohasset, and two at Scituate. They are small motors, the largest about 16 horse-power and, I think, too small for producer-gas plants. Our experience in both places has been very satisfactory as far as the cost of pumping is concerned, and that is what we are looking for.

I do not feel like discussing this thing because I hardly know what to say. If anybody wants to ask any questions, either Mr. Thomas or myself will try to answer them. [Applause.]

The President. I should like to ask Mr. Gowing what he considers the limit of these gas-producer engines.

Mr. Gowing. Which limit, up or down?

The President. The limit as regards large size, I mean.

Mr. Gowing. Oh, I don't know. If I were going to put in a pumping plant up to 100 or 200 horse-power, I think I should put in producer-gas, and probably divide it up into as many units as seemed best, so that in case of breakdown I would not be left without some power; in fact, for a 200 horse-power plant, I should like to have three 100 horse-power units and then I would be sure of having 200 horse-power all the time.

The upper limit I don't know much about. I understand that there are some very large producer-gas plants which are doing well.

I think producer-gas is used more in the territory west of the Hudson River than east of it. In regard to such things New England water-works men are a good deal like New England railroad

men; improvements in railroads usually start in the West and move East. This is a matter which is received with more favor in the West than here.

Mr. Frank A. Barbour.* In 1906 the town of St. Stephen, N. B., in connection with the new water supply, installed a gas producer plant exactly similar to that described by Mr. Thomas, but of a larger size. The installation included two producers, each of 135 horse-power nominal capacity, two engines of 125 horse-power nominal capacity, and two triplex double-acting power pumps which, running 32 revolutions per minute, have a capacity of 1 800 000 gallons each per twenty-four hours.

The fuel available in St. Stephen is Nova Scotia bituminous and American pea anthracite, obtainable at practically equal cost of about $5 per ton. The choice between a steam and gas-producer plant was made dependent on actual propositions on both types, bids being called for under the same general specification, with a requirement that bidders should guarantee a station duty, including banking and all standby losses, these to be determined by a three-day test with the engines running eight hours each day and banked the remaining sixteen hours. It was considered that a test of at least this length was necessary to get results of any value from the gas plant, and also that such a test would be the best practical expression of the actual commercial value of the plant. It is to be noted that the inclusion of the banking charge in the duty made the comparison more favorable to the gas producer, as the latter type of plant can be banked with but a small fraction of the fuel necessary for a steam plant of equal capacity.

Propositions were received from two builders of steam plants and from three builders of gas plants. The first cost of the steam plants ranged from 50 to 80 per cent. of that of the gas plants, but the guaranteed economy was also sufficiently lower to make the gas plant the more economical proposition. The work was awarded to the Olds Gas Power Company at a price, including producers, engines, pumps, and auxiliary apparatus, equal to about $100 per horse-power of engine, including the customs duty into Canada. As the engines are larger than necessary for the work of the pumps it may perhaps be reasonable to estimate the

* Civil Engineer, Boston, Mass.

cost per horse-power of such a plant at about $75 in New England.

The duty guaranteed was 115 000 000 foot-pounds per 100 pounds of pea anthracite coal, having a thermal value of 13 000 B. T. U., with not to exceed 10 per cent. ash nor 2 per cent. sulphur.

During the early days of trying out this plant the same troubles as described by Mr. Thomas were encountered, and a better description of the trials which any one will almost surely meet in getting acquainted with producer operation could not be presented. Unquestionably there are in this work more factors each of which may affect results and which demand consideration than with steam work. Any one can boil water without burning it, while relatively few men have any inherited knowledge of the processes necessary to the making of gas of a certain character. Operators for steam plants can easily be found who will readily make them go, whether economically or not being another question; while in producer work the apparatus must be handled about right in order to run at all, but if it goes it runs with good economy.

The difficulties encountered are usually confined to the producer end of the plant or in the making of the gas. The engine troubles, if any, are largely mechanical and readily corrected by the average mechanic. Because knowledge acquired by experiences such as those described by Mr. Thomas is necessary to the successful operation of such plants is no reason to conclude that the element of reliability is lacking. This Association is to be congratulated on the presentation of this valuable paper, but there is also a danger that incorrect inferences will be drawn from this frank statement of the troubles encountered in the early work, and attention should be called to the fact that, after the preliminary difficulties, the apparatus has worked with success and is to be duplicated in the enlargement of the plant. The experience at St. Stephen was very similar, as, after the early difficulties, the plant was left in the hands of a local engineer who is running it without any trouble, although previous to his acquaintance with this plant he had been engaged on steam work.

I think, further, it may perhaps be due to the builders of the plant to say that until the apparatus was in successful operation they did not expect it to be taken over by the town.

In the test at St. Stephen a duty of 125 000 000 foot-pounds per 100 pounds of coal fired, including banking and all standby losses, and with the water used in cooling and in compressing air for starting and blowing hot charged to the plant, was obtained. The coal was below the contract in thermal value, running about 12 000 B. T. U. per pound. The duty was, therefore, equivalent to 100 000-000 foot-pounds per 1 000 000 heat units.

The small amount of fuel used in banking the producer during the sixteen hours of idleness is notable. During the test this averaged 22 pounds for each generator, or equal to about 3 per cent. of the total coal, or about $\frac{1}{100}$ of a pound per hour of banking per nominal horse-power of generator. During another ten days' run the amount used in banking averaged 52 pounds or about 7 per cent. of the total coal used.

In the test, as in actual work, the ashes and coal lost in stoking from the door above the grate were screened and re-fired. The amount of material so screened depends on the operator, and experience in St. Stephen up to the present time decidedly indicates the economy of re-firing the salvage.

In actual running the plant has developed a station duty of somewhat over 120 000 000 foot-pounds per 100 pounds of coal, although the coal contains about 15 per cent. ash, and the engine is running at less than three-fourths of its nominal capacity. This approach to the test duty in every-day operation is worthy of note. Steam duties are usually based on ten-hour tests, and the average station duty, including banking, rarely exceeds 75 per cent. of the test duty. With producers there does not exist the same chance of running up the test duty by expert firing as in steam, and the result is a commercial economy more nearly equal to that found in the test.

The obtaining of pea anthracite coal best suited to the work is a matter to which considerable attention must be given by those operating this type of plant. The amount of incombustible material or ash in the coal does not seriously interfere with the operation of the generator, but it increases the labor in firing and in screening salvage. Sulphur, however, is an element to be strenuously avoided. As to the ash, it is difficult to obtain pea coal with less than 12 per cent. incombustible material. Analysis of

samples recently collected at twelve different collieries show an average ash of 13.63 per cent., with a minimum of 10.92 per cent., and a maximum of 20.65 per cent. In future contracts it would not be unreasonable to specify that the work shall be done with coal containing not more than 14 per cent. ash. Practically the user of producer plants must take commercial pea coal, as the mine agents will not sell according to specifications. If the coal is obtained from local wharves it usually contains, unless screened, so much sweepings and dirt, that the ash contents will run well over 15 per cent. If specially screened, it of course costs more than the average market price. The best way to obtain suitable coal is to buy direct from some colliery where the ash content is reasonably low and sulphur is known, by analysis, to be not present in dangerous amounts. The recent increased demand for small anthracite has resulted in an increased value of at least $1 per ton for this coal over the prices of a few years ago, and in future it will probably be well, in considering the relative economy of producer plants, to figure on a value of pea coal more nearly equal to that of the larger sizes of anthracite than it has been in the past.

In any particular problem of water-works pumping the choice of plant must rest on the relative cost of fuel, the size of the plant, and certain conditions in the method of distribution. Between the small sizes where heavy oil engines have a field and the larger sizes in which high class triple vertical steam engines are justifiable, the gas producer plant is certainly worthy of careful consideration. Its first cost will be more than that of a steam plant, its floor space practically the same, and its necessary attendance but little different. Its reliability, if properly constructed, is probably equal to steam. What may be the relative depreciation of a gas producer plant cannot perhaps be as yet predicated, but in every-day economy it greatly outclasses all but the highest grade of steam engines.

The President. Is there anything further to be said on this subject?

Mr. S. H. McKenzie. Mr. President, I might say for the information of those who come from the central part of Connecticut that in our town of Southington we have a 100 horse-power gas-producer plant which was recently installed by a drop forging concern. The manager took me in to see the plant the other day

and he couldn't say enough in praise of it; he said it was far superior to a 50 horse-power gasoline plant which he had been running, and I might say that it works beautifully.

The President. Have you any idea of the duty which the plant is developing?

Mr. McKenzie. I couldn't say.

Mr. A. O. Doane. I should like to ask how long it would take to start up, with the generator and everything cold, to blow up a fire and get it all started. I thought from what Mr. Thomas said it might take a long time to get the fire blown up and get the right quality of gas and everything, building a new fire.

Mr. Thomas. I am unable to answer the question in a manner that would be entirely satisfactory to Mr. Doane, for the reason that our needs have always allowed us to take plenty of time in starting our plant. I said in the course of my paper that we obtained a good test of gas at the generator after blowing the fire for an hour, and there is no reason why, as soon after this as a good test of gas is obtained at the engine, the plant should not be running. Please bear in mind that these conditions refer to starting up the plant after its having been shut down some time, with an absolutely fresh fire and everything cold. When starting up with a fire that has been banked over night we have, in our operating, had everything running in thirty minutes from the time the engineer arrived at the station, and in one or two instances this has been reduced to twenty minutes.

I trust no one will draw the conclusion from the paper that we are in any degree disappointed in our plant; on the contrary, we are altogether pleased. In considering what was best to incorporate in the paper, I selected experiences which should be accurate and interesting, and naturally enough these came during the first season. The operating from which material results was obtained came later and these were summed up in the closing pages of the paper, to which I again call your attention, and by carefully referring to these it will readily be seen what excellent service our plant is giving.

A FEW WORDS ABOUT HOLLOW CONCRETE-STEEL DAMS.

BY CHARLES H. EGLEE, HYDRAULIC ENGINEER, BOSTON.

[*December 11, 1907.*]

Mr. President and Gentlemen: I hardly think that the few words which I shall speak in relation to this subject should be dignified by the name of "paper," which implies that something has been specially prepared for the occasion. I feel a certain hesitancy in addressing this Association on this subject for several reasons, the first being that I am associated with a company whose business is the designing and the building of hollow concrete-steel dams. This is a very personal matter, and being, as you know, naturally of a shrinking and modest disposition [laughter], which has been, I might say, increased by a number of years' experience among you as a contractor [laughter], there is a natural delicacy in intruding upon you a subject with which I am so intimately and personally connected. Then, again, I hesitate because the company of which I have spoken has been very industriously engaged for the past few years in presenting to the public, through its literature, which has been very lavishly sent out all over the country, the principles of design and the methods of construction of this peculiar structure. Also, these methods and these designs have been the subject of a number of engineering and quasi-engineering articles that have appeared from time to time in the engineering papers under the form of paid advertisements.

I hardly know how to present to your mind's eye a picture of a modern hollow concrete and steel dam used for the impounding of water, or used for the creation of power on a stream. I presume that most of the members present are not particularly interested in power dams, but are more particularly interested in reservoir dams. I shall endeavor to draw, as well as words will permit me, a picture of a modern method of constructing for reservoir purposes a concrete-steel dam, such as is now being constructed by the city of Pittsfield.

Imagine, therefore, that the site of your dam has been cleared of brush, etc., and the foundation for the dam prepared, — just such a foundation as you would prepare for an ordinary earth and core-wall dam, the vegetable matter, mold, and muck being removed to reach a solid foundation. This, then, stretching at right angles to the stream across the valley, is ready for the reception of the dam. On this prepared surface is laid a flooring of concrete, not following the slopes of the ground, but being laid in horizontal planes and stepped up upon the slopes as we approach the summit or crest of the dam. Of course, as we step up, the concrete base is gradually narrowed until we reach the top.

This flooring of concrete is thoroughly interlaced with bars of steel. These bars of steel are computed of the proper size for resisting the pressure which will be brought to bear upon this foundation, and the concrete foundation is computed to be of a proper thickness to support the superstructure.

Imagine, then, that this floor has been spread. Upon the upstream side or heel of the dam a cut-off wall, corresponding to the ordinary core-wall, is sunk down through the loose strata until it reaches an impervious stratum, either of rock or of clay, so that the water will not pass underneath the wall. That is the ordinary core-wall construction in any ordinary dam, but in this dam it is placed upon the upstream side of the dam, — made of the best quality of concrete, thoroughly connected to the floor by means of steel reinforcing rods. On the lower or downstream side, at the front of the dam, there is another wall sunk, not to any considerable depth, but far enough so it secures between the walls all of the foundation earth material beneath the floor of the dam. This floor is pierced with holes, which are called "weep-holes," in order that if the cut-off wall should not thoroughly cut off the water, or if it should not be thoroughly connected with the underground and underwater impervious stratum, the water finds instant relief and comes up through these "weep-holes." Also, if there is a leak in the cut-off wall, these "weep-holes" will show where that leak is, and it may be repaired. That is the purpose of these "weep-holes," although I have never yet seen any of them weep.

Upon this floor there are erected piers, or what are technically termed "buttresses," which are the support of the dam proper.

These buttresses are erected parallel to the course of the stream, at right angles to the longest diameter of the floor, and rise from this floor up to the crest of the dam. In the instance of which I speak, at Pittsfield, they will be, at the highest point, 40 feet in height. These buttresses do not rise at the same width all the way up, but at every 10 feet of elevation they are stepped in and gradually narrowed until they come to the top. These buttresses are also reinforced with steel rods, and they are computed so that they shall be of such a size as will resist the crushing pressure of the water that is brought to bear upon the dam.

In the preparation of the floor, proper corrugations or steps are cut to receive these buttresses, and each one of them fits into its own particular place; and they are spaced from 10 feet apart to a somewhat larger space than that, as the structure requires. On the Pittsfield dam they are spaced 12 feet center to center. Upon a very soft foundation they would not be spaced so far apart; upon a rock foundation they might be spaced still farther apart. In one instance which I recall they are 18 feet apart, and in that instance the buttresses expand toward the water-bearing surface of the dam into "haunches," which receive the deck or the barrier proper to the water.

After these buttresses are in position a sheet of concrete is laid on the upstream side covering the buttresses all the way from the cut-off wall up to the top or crest of the dam. This sheet of concrete is thoroughly and completely interlaced with steel reinforcing rods and is made of the very best quality of concrete that is known at the present stage of the art. After this sheet of concrete or deck is laid from the bottom of the dam up to the top, the dam is complete.

You must not understand by this description, however, that all of these different processes are taken up consecutively, as I have explained them. In fact, all of these processes usually are going on at the same time. The excavation for the cut-off wall is progressing, behind that the floor is being laid, still further in the rear the first lift of the buttresses is being put up, and still further in the rear of that the deck is being spread on; so that the dam goes up, as it were, from the bottom to the top in a regular progressive order, and not in the order I have previously explained.

When this dam is completed, if you walk upstream to approach

PLATE I.

DAM AT CAIRO, NEW YORK.

the dam it has the appearance to you, more than anything else, of a series of gigantic horse stalls. (See Plate I.) The front of the dam being entirely open, you walk into the dam under the water. You walk over the floor until you have reached the deck of the dam. The dam is perfectly open to you, you can inspect it in any part, and as you stand there and look up to the height of 40 feet and then realize that between you and the water there is only a thickness of about 2 feet or 27 inches of concrete, and when you look at that concrete and see that it is perfectly dry and perfectly hard, you wonder why people haven't built that sort of a dam before, because it is so extremely simple.

I am not going at this time into any of the calculations or computations that are very carefully made in the designing of this dam; nor am I going to explain at this time why the buttresses are spaced as they are, or why the thickness of the deck should be what it is; but I am merely trying to give you in the few minutes allotted to me a description of such a dam which you can carry in your mind's eye.

This describes only a dam of the open-front storage type, but the principle is capable of so many different variations, and is so adaptable to almost every situation, that a very great length of time could be consumed in the explanation of all its peculiar features. Take, for instance, in this particular dam, the matter of an overflow or spillway. In about the center of the dam, over the bed of the brook, the buttresses on the front or downstream side of the dam are not shaped as are the majority of the buttresses, with a little incline toward the top, but they are shaped in a curve, an ogee curve, and that curve is overlaid with an apron of concrete in the same way that the deck is made. The crest is reduced a couple of feet in height at that point, and you have your overflow or spillway constructed which returns the overflow water directly into the old bed of the brook.

Elaborating that one particular feature, and carrying the apron all the way across the dam, you then have a dam that is entirely enclosed. It has the deck on the back, it has the apron on the front, and such a dam as that is put across a river where heavy logs are being driven, or where there is a large flow of ice when the stream breaks up in the springtime, and those logs, that water,

and that ice are returned to the bed of the stream over this apron which entirely encloses the lower part or front of the dam, the entire dam remaining open within. The fact that the dam is open at all times is a feature that is very commendable indeed, because that space can be utilized for so many different purposes. Take a dam like the Pittsfield dam, which is open at all times and easy of access, those spaces between the buttresses beneath the dam are used for the storage of tools or material. Within these spaces are the gate-chambers, the screens, the valves which control the flow of water to the city. They are all easy of access, and no special or particular gate-house is required. If the dam is used for power, as is the case of a dam in Maine, that part of the dam which is not used as a spillway or overflow for the water is enclosed in the front, there are different floors laid in the buttresses at different heights which are connected by iron stairways; the whole interior of the dam is warmed, is lighted by electricity, and these rooms are used for transformer rooms, for the storage of electrical material, for tools, for coal storage, for work shops, lathes are set up within them, and the whole operation of the maintenance of the dam, all the business that pertains to it, is carried on within the dam itself, even including the office of the works.

Another feature which is commendable in the openness of the interior of the dam is the fact that it is at all times accessible and open to inspection. There is no portion of a hollow concrete steel dam that cannot be visited at any time. We therefore know whether our dam is in good service, whether there are cracks or leaks in it, whether there are any repairs necessary, or whether there is any deterioration at any time. If those things should be discovered, they are very easily repaired; I don't know exactly how, because no repairs have yet been found necessary. But still it is a comfort to know that you can look at your dam inside and at any time you want to.

This interior space, too, in power developments, is frequently used for the installation of hydraulic and electric machinery. You take a dam that is from 50 to 100 feet in height — I recall two at the present time 70 feet in height — in which all of the machinery for the generation of electricity is contained under the roll-way,

under the crest of the dam. One of those dams is located in a very peculiar situation, in a box canyon in the West. There is no situation below the dam for a power house. The river is subject to extreme floods at times, cloud bursts, etc., and all the water that goes over the dam is concentrated into this narrow canyon. There is no place to put a power house, and if a power house could be put there the river would be constricted to such an extent that the house would be in danger of being washed away. Therefore, the whole apparatus is put within the dam itself, and all the water that goes over the spillway goes over the apparatus, excepting that which is carried into the dam for use in generating power. This dam is located so peculiarly that there is no opportunity even of getting the machinery into the power house until the dam is constructed. After the dam is finished and the pond filled, the machinery is floated down to the dam on bateaux and lifted up by derricks which are set in the rock and dropped down into the dam itself, and then installed. Probably no other dam could have been constructed in this peculiar situation, and it was necessary that a dam should be constructed there because there are extensive operations going on in that locality which require power, and coal is from $15 to $20 a ton.

The appearance of an open dam such as I have attempted to describe is best shown by Plate I. Here is a dam built for the generation of power, the two penstocks coming out through the bulkhead of the dam on the lefthand side of the picture, and the front of the buttresses showing that peculiar stall-like effect of which I spoke. When the water goes over the spillway of this dam, of course that effect is not visible. At the time this picture was made, the water was running through the dam, before the pond had been closed.

That brings me to another peculiar feature regarding these dams. As we build them in a river, we leave the lower part of the deck off of two or three or more of these spaces between the buttresses, and when we change our cofferdam and turn the river in the other direction, we permit the river to run through those spaces. You see that in this cut; the water is running through between certain of the buttresses; the lower part of the deck on the upstream side of the dam has not yet been put in place. Now, when the time

comes that we wish to fill this pond and permit the water to run over the top of the dam, those orifices must be closed. Formerly in the closing of a solid dam there were expensive works necessary, in the construction of cofferdams, etc., so that the concrete could be placed in security. But in this instance no such cofferdam is required. The orifices are fitted with grooves in the concrete at the back, and when we wish to close them up we merely construct a wooden gate and drop that gate, which is a series of stop-logs, into these grooves, and we shut the water off from running through the dam. Then we go inside the dam, and behind the shelter of these stop-logs we put in a drainage pipe which takes the water that will come through the little cracks of the logs and will carry that water away, and then within that security we build our forms and put in our concrete and permit the water to rise on the dam while we are doing it. Nothing will disturb the workmen, because they are inside under the shelter of the deck. We have all the opportunity we want, so far as time is concerned, and we can permit the concrete to remain there and set up just as long as ever it wants to, until it becomes as firm as all the rest of the dam is, thereby avoiding a very great deal of expense in cofferdamming and in pumping.

In fact this feature, further elaborated, permits us, as has been done in one or two instances, to build the entire dam all the way across the river on piers, without any cofferdam at all. This practice obtains, however, only when the river is of a moderate depth, one or two feet, and has a rock bottom. Under these circumstances caissons or piers are built and filled with concrete and brought up one after the other to above the level of the water, the river continuing to flow all the time. We have then a series of what appear to be stepping stones all the way across. Upon these stepping-stones scaffolds are erected and the superstructure of the dam is carried on, the river meantime continuing to flow underneath the dam. When the time comes to close these orifices, to stop the flow of the river, they are taken up one after the other, stop-logs are put down, and they are masoned up or concreted up from the inside.

The dam as it appears to you seems to be a very slight and skeleton-like structure as you approach it. The buttresses are

not very thick, about 2 feet, as I remember it, at the bottom, on this Pittsfield dam, which is 40 feet high; but as you approach nearer to it, get close to it, and within it, it has an entirely different effect upon you, particularly if you go within a dam that is entirely closed, both on the upstream and downstream side, having a complete deck and apron. The appearance of a massive structure under those conditions strikes you at once. It seems as though it was almost impossible that anything could occur that would affect the solidity and the permanence of that structure. It is necessary, however, very frequently that the permanence and stability of the structure should be well demonstrated in advance, before the structures are built. It will not do to say in many instances that this is so-and-so and it is so because I say so. That is a very bad attitude to assume when you are endeavoring to show to a person any new feature or any bold engineering, and *this is* bold engineering. Therefore the most minute and intimate calculations of all stresses and strains and compressions and pressures of all kinds are made upon each individual dam before anything is ever done in the perfection of its design. That is a feature that it is impossible to speak further of at this time. But there is one feature that is very frequently spoken of that ought to be brought to your attention, and that is the impermeability of the concrete which is used in the barrier to the water — the deck of the dam.

This deck is placed at an angle to the perpendicular, shown, in Fig. 1. This shows a full deck and apron dam, and is built on the Battenkill River. I want to speak to you about the angle that the deck presents to the water. That is the same principle that was used by our forefathers in the building of their old-fashioned wooden dams. There is nothing new about that. I believe that the beavers are still continuing to build that same kind of a dam. But the angle that the deck makes from the perpendicular is adjusted to each different problem as it is presented. This one shows that the angle of inclination from the perpendicular is about 45 degrees, or 1 to 1. Had that dam been built upon a soft bottom, requiring a floor, that angle from the perpendicular would have been greater, probably 52 or even 55 degrees, or an incline of 5 to 4, in order that there might be more pressure brought

in a perpendicular direction upon the foundation supporting the dam. It depends altogether upon what sort of a foundation is underneath a dam as to what the angle of the deck should be, and that is always the subject of very close computation. Also the thickness of the floor of a dam is computed to resist the pressures that are brought to bear upon it.

I have digressed somewhat from what I was going to speak about in relation to this deck, and that is the impermeability of the concrete which constitutes it. When this dam was first brought to my attention, and I looked into the designs, I said at

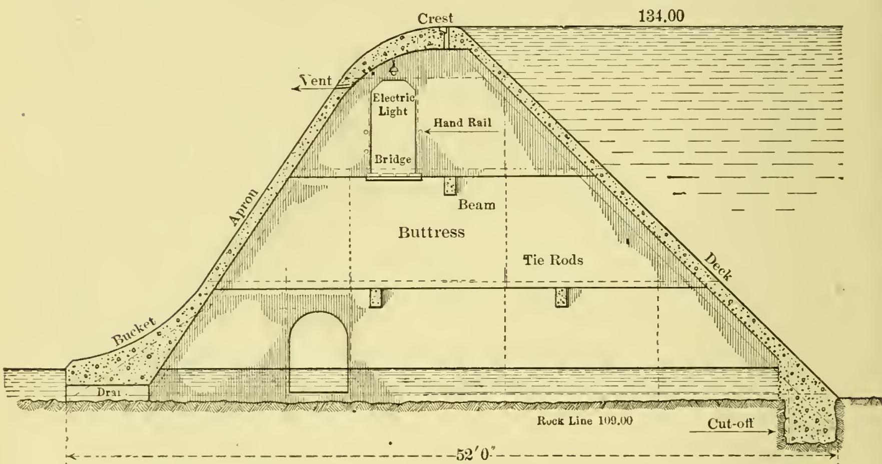


FIG. 1. SECTION OF HOLLOW CONCRETE-STEEL DAM.

once, "The whole thing is a failure; there is no necessity of going very much further into this thing because the deck will leak. Eighteen inches or two feet of concrete will not resist the pressure of water that is brought to bear upon it." And the representative of this company said to me, "How do you know?" "Well," I said, "in a modest way, for twenty-five years I have been putting in concrete; I have been putting in concrete as a contractor, to be sure, but sometimes we get in very good concrete. [Laughter.] In fact, some of the engineers with whom I have been employed have been very highly complimented on account of the concrete which I have put in. [Laughter.] And I know that two feet of concrete

is not enough. Why, the Metropolitan Water Board, when they wanted to hold 15 feet of water, put in a wall of concrete 7 feet thick, and then they weren't quite sure." Well, the president of this company said to me, " You remind me of that old story about the man in jail, whose lawyer told him they couldn't put him in jail for the offense for which he was committed; and the man said, ' Well, it don't make a particle of difference about that, I am *in.* ' " He didn't know how old the story was when he told it to me; if he had he wouldn't have told it; but it illustrated the case, because they *were* putting in the concrete, and I went and looked at it and it was a fact. And when I took my handkerchief out, in the interior of the dam, to wipe off the moisture from under side of the deck, it wiped off dust. There wasn't any moisture. That is a sure test. The concrete in the decks of hollow concrete-steel dams, well put in, mixed with fine aggregates, with plenty of cement and rather an overplus of water, more than is required for crystallization, — such a concrete as that will not leak.

Many have asked whether in the treatment of the deck of this dam there is any special preparation used. Nothing whatever is used. There isn't even a coat of plaster put on the water surface of the dam.

One great help, however, to the impermeability of concrete, which has lately been discussed, is the chemical action that takes place in concrete when exposed to water. The free lime in the cement is formed into carbonates by the action of the water in all the little minute voids which necessarily exist in any concrete, an action being set up exactly similar to the formation of stalactites in a limestone cave; and all these little minute voids are in time filled up with strong carbonates of lime. The water never penetrates beyond these, and this action is begun at the time that the water is brought in contact with the concrete surface and continues up to the time that all the voids are entirely filled. These carbonates of lime will not fill large voids. There must be no large voids in the concrete; the voids between the stones must be filled with the sand and with the cement, and the concrete when mixed must be mixed very wet. If you will notice in the mixing of concrete, where you use an overplus of water, the free water will run out from the forms, but it will not carry the cement with

it; it runs clear from the top, almost as clear as clear water; there is very little sediment. It is a strange thing how much water is required in the crystallization of concrete. There is very little, if any, absorption of moisture by the atmosphere. When you put concrete into a form and allow it to set, you take the form off and you find that the concrete is at the same level that it was when it was put in very wet. There has been no shrinking, at least no appreciable shrinking, although there is undoubtedly a slight shrinking which is carried on from that time until the concrete has got its formal and final set. It is perfectly wonderful how concrete put in in that manner, with due care and with fine aggregates, will resist the penetrating action of water brought to bear upon it under a pressure.

I was told I might speak just so long, and I find I have spoken two minutes over time. If there are any questions that may come to your minds in relation to this matter, for there are very many points upon which I have had no opportunity to touch, I should be very glad to endeavor to answer such question as you may wish to ask.

DISCUSSION.

THE PRESIDENT. Mr. Eglee inquired how long I wanted him to speak, and I asked him how long he could talk on the subject. He said two weeks. [Laughter.] I told him we would try 40 minutes. The subject is now open for discussion, and I think Mr. Eglee will be very glad to answer any question which may be asked.

MR. COGGESHALL. I should like to ask Mr. Eglee if it would be possible to build a reservoir on this principle.

MR. EGLEE. There has been a reservoir built in Waltham, lately, on the principle of a reinforced concrete-steel standpipe, 100 feet in diameter and 40 feet in height. I had the misfortune to build a standpipe of that character some few years ago, and when I finished it it was not tight, and it has never been tight since. There was one built for the city of Attleboro also. That, when built, was not tight, but the reasons for that were many and varied. They had nothing whatever to do with the concrete, which in both instances was of a very acceptable quality. In the instance that I cite, where I built a standpipe of that character, I believe that the problem was altogether too new in the mind of the contractor

and engineer, and it certainly was too new in my own mind, and I have always thought the fault was in the design. I believe that the fault in the Attleboro standpipe was more in the instability of the forms retaining the concrete than in anything else. They were permitted to slip once or twice.

We have designed several reservoirs, to be placed on an elevation, in which there was a floor laid, and on this floor a structure built exactly similar to the one I have been endeavoring to describe, — not round, but coming together at angles. I think the ones we designed were octagonal in shape. The principle was exactly the same. Let me say here, too, that the difficulties in the computations of a structure of that character are almost nothing compared with the difficulties of design of a regular standpipe. The difficulties of design and computation necessary in a dam of concrete-steel are as nothing as compared with the difficulties in computation and design of an ordinary concrete-steel building, which is put up every day.

Mr. Sullivan. I am a little curious to find out what effect expansion and contraction has?

Mr. Eglee. I am very glad you have touched upon that point. The hollow concrete-steel dam is not a monolithic structure. It resembles, perhaps remotely, a house of cards. It does not fall down that way, but it is put up that way. Each buttress is divided at certain points; and the floor is divided at certain points; the deck is divided in horizontal spacings of 30 feet in small dams, and in large dams every bay (the space between the buttresses) is divided in construction. All these joints made throughout the dam are for the purpose of expansion and contraction. There is a movement in every dam; it does not make any difference how it is constructed, whether it be of masonry or of solid concrete or of concrete and steel, there is a movement due to expansion and contraction. I think if there was any one here from New Haven at the present time he would be able to give an instance of temperature cracks that have already appeared in the new solid concrete dam which was built there this season. The hollow dam, however, takes care of that expansion and contraction by these expansion joints which are left in the dam for that purpose.

Mr. McKenzie. I understand that you do provide an expan-

sion joint in the decks once in 30 feet; that is, that the reinforcing rods do not cross that expansion joint, but are separated entirely at the ends.

Mr. Eglee. Yes, sir. If the buttresses are spaced, we will say, at 10 feet, then when the deck is put on it covers three buttresses and stops in the center of the third buttress. The next section of the deck covers 30 feet from that. There is no particular expansion joint made there; the work merely butts up to that and stops; the steel stops at that point, and there is a corrugation made, or a rabbet made, in the deck concrete at that point; and when the next section of the deck is put on the new concrete fills up the rabbet. That joint opens and closes. It is perceptible. If the concrete is laid in very hot weather, in the middle of the winter you can put your finger in the cracks.

Mr. McKenzie. You consider that 30 feet is the proper distance between the joints?

Mr. Eglee. It isn't always 30 feet; it depends on the thickness of the slab of concrete. In dams which are lower than 40 feet in height, we have determined that 30 feet is the proper distance for the expansion joints; at Pittsfield the distance is 25 feet, covering two buttresses.

Mr. McKenzie. I noticed in the New Haven filtration works, while there were no expansion joints, that once in about 14 to 18 feet it pulled open, even where the rods crossed, so that there was an opening of perhaps one sixteenth of an inch.

Mr. Eglee. That is very true. That pull is very perceptible. I can cite an instance of that in a certain dam in Vermont, where for some reason or other there were two steel rods which projected from one of the buttresses into the deck. There was an expansion joint which came upon that very buttress, and one of these rods was in the deck on one side of the expansion joint and the other rod was on the other side. The pull from contraction was strong enough to split the buttress vertically between the rods, and the deck opened just about as wide as my finger.

Mr. McKenzie. May I inquire also if you have not thickened up the concrete on the deck and on the apron from the original plans or from your practice of two or three years ago?

Mr. Eglee. Yes, sir. We have thickened the concrete on the

deck and the apron of the dam as a concession to public opinion. There is no necessity for a thickness of that kind, but it is very difficult to convince the building public that there is not such a necessity. We are also in such a position that we cannot make our buttresses as thin as the computation calls for. We put in a surplus quantity of material in the buttresses, but we save concrete by cutting out large openings in the buttresses.

Mr. McKenzie. May I inquire if you have not also increased the thickness of the concrete outside of the reinforcing rods; that is, originally weren't they about 1 inch in from the outer surface, whereas now they are at a greater depth from the outer surface?

Mr. Eglee. That is caused by a difference in construction, merely. We want to put our reinforcing rods as near to the lower side of the deck as possible. The deck is computed as a beam which sustains a certain pressure. That beam rests from center to center of buttress. We therefore want to get our steel reinforcement as low into that beam as we possibly can; so we put our steel within one inch of the under surface. But a difference in construction has shown us that it is wise to drop our deck below the buttress and key it over the buttress a little bit. By doing that we obviate the necessity of building lateral beams between the buttresses. In dropping the under side of that deck 1 inch to give it that lap over the buttresses, it has made the steel 1 inch nearer to the water surface, and we have put 1 inch more concrete on on that account.

Mr. McKenzie. What is the average depth from the surface of the concrete to the outer side of the rods in the deck and apron?

Mr. Eglee. That is a difficult question to answer. I can say that at the top, near the crest of the dam, usually the depth is 10 inches, unless the dam is in a river subject to heavy ice runs. In that case it is thickened considerably. In a water-works dam, like the reservoir dam at Pittsfield, I think the distance is 10 inches. The thickness increases all the way down to the bottom, depending upon the height of the dam.

Mr. McKenzie. I had more particular reference to the matter of the penetration of the water and to the corrosion of the rods with respect to the depth that they were sunk in the concrete.

Mr. Eglee. I am glad you have brought up that question of corrosion of the rods. There is no corrosion of the rods. That has been demonstrated in various ways. In the first place, the rods are very close to the inner edge of the concrete. There is nothing shows more distinctly on concrete than rust. If water penetrated through that concrete and attacked those rods, the pressure of the water on the outside would force it through to the inside, and there would immediately be a stain of rust there. There is a stain of rust everywhere that we put a bolt through the concrete. We put bolts through the deck at the buttresses in order to hold our false work, our forms, and we set those bolts in a gas pipe in order that they may be removed. Every one of those gas pipes streaks the concrete with rust. It is not necessary to let the water rise; the very first rain will do that. If the water penetrated into the concrete and attacked those rods, we would know it immediately, because the rust would stain the inside.

Another proof that the rods are not attacked by the water is that there is no moisture on the inside of a dam excepting the moisture from condensation from the atmosphere. On a clear, crisp, dry, windy day there is no moisture on the inside of a dam; on a warm, muggy day there is always moisture dripping from the inside of the deck, caused by the coolness of the water on the outside.

Mr. D. E. Makepeace. I should like to state with regard to the standpipe in Attleboro, that it is absolutely tight and has been so for a long time.

Mr. Eglee. I beg to apologize, sir. I ought to have said that at the time of my last information, which was gathered at the time of the reading of the paper on the Attleboro standpipe, at the Annual Meeting at the White Mountains, the Attleboro standpipe, according to the statement in the paper there read, was not tight. And the reason which I have given for that, viz., some irregularity in the building of the forms, is what I gathered from the same paper. I am glad it is tight.

The President. Mr. Winslow, how is it about the Waltham standpipe?

Mr. Winslow. I don't know that Mr. Eglee said that that leaked.

Mr. Eglee. I think I should have said that the gentleman who built that standpipe informed me that it was absolutely and per-

fectly tight; that there never had been a repair of any character whatever upon it, and that it was a very satisfactory piece of work.

Mr. Richard A. Hale. I should like to ask Mr. Eglee if any special provision has been made in the form of the dam on large rivers like the Merrimac and Connecticut, where there is very heavy ice and where large quantities of logs frequently come down. Take it at high water in the Merrimac, ice is often two or three feet in thickness, and sometimes a boom of logs breaks away and comes down, and there is a great deal of trouble at the dam. I would like to ask whether special provision should not be made in the construction of a dam on such streams.

Mr. Eglee. Yes, sir. Special provision is made for the protection of the dam always. There is a dam built on the Missisquoi River, at Sheldon Springs, Vt. Before that dam was built, three dams had been carried away on that site within the previous seven years by ice gorges. The river there is very much constricted. The ice forms and comes down with a solid impact against the dam. To avoid that the deck of the dam is broken in its angle, and instead of going straight up from the bottom to the top like that, it goes up this way [illustrating], and then there is an easier slope which catches the ice and conveys it over the crest of the dam; and the same with logs. When the logs or the ice have gone over the crest of the dam, they are received by the apron and delivered upon a bucket. That bucket returns them to the river in as nearly a horizontal plane as can be computed. The ice and logs come down there very swiftly and heavily and strike on that bucket with force, unless there is a water cushion; therefore that bucket is made deeper and thicker and is very solid, computed to the necessities of the case.

I have spoken in my illustration of a dam 40 feet in height. When these dams were first being constructed it was presumed that when we reached a height of 25 or 30 feet we had reached the limit. Dams, however, are now under contract 100 and 150 feet in height on this same construction; and studies have lately been perfected for the government — which studies they do not expect to use, but they wish computations for — for this class of work under a head of 300 feet.

PROTECTING WATER PIPES FROM FREEZING.

[*Topical Discussion, January 8, 1908.*]

The President. I want to ask some of the members to tell me what is a good, practically indestructible, cheap packing for water pipes over bridges. We have a case in Newton of a fairly long line of 16-inch main crossing a bridge, through which the flow is rather sluggish. If it wasn't so, we would probably leave the pipe as it is; but we are rather fearful that in severe weather the pipe may possibly get caught. We don't wish to use anything that is very expensive, and we don't wish to put in something which will rot out within a few years. I felt sure that I would get a suggestion from some of the members here to-day.

Mr. R. C. P. Coggeshall. I think I can say something, Mr. President. We have a bridge which connects our city with Fairhaven, which is located on the opposite side of our river. A few hundred feet from the New Bedford shore this bridge passes across a small island. The water between the New Bedford shore and this island was formerly the ship channel and here a draw in the bridge was located. Formerly, this island was supplied by a 2-inch lead pipe laid across the bottom of this channel. We had frequent trouble with it on account of freezing, which we attributed to anchor ice. This bridge was replaced by a new structure about five years ago, and as the draw was then located in another section, it was not necessary to longer continue the siphon to supply this island. Accordingly, a 6-inch pipe was laid upon a platform passage-way suspended from the bridge beneath the floor. This pipe was tightly covered with double boxing, with an air space between the two. This was done in 1902. We have had some severe winters since, but no trouble from that pipe. I thoroughly believe that a good "air space" is the best preventive of frost action.

Mr. Frank L. Fuller. Mr. President, I agree with Mr. Coggeshall. I have laid pipes over bridges in a great many instances, and double boxing has always been sufficient to prevent

the pipe from freezing. When we built the Wellesley works, we thought we would pack the pipe with tan-bark, but that soon became saturated with moisture and froze up solid, and I think that same winter, on account of the freezing of this mass of tan-bark around the pipe, the pipe also became frozen solid. I think we have had one or two cases where with double boxing and an air space the pipes have caught, but the pipes never have been frozen sufficiently to burst; and I think that where the circulation is at all good that is sufficient. In the place that is spoken of by the president, possibly still another boxing would be an additional protection. I am sure from my experience that an air space is much better than it is to put any substance around the pipes.

ONE YEAR'S PRACTICAL EVERYDAY EXPERIENCE WITH AN AUTOMOBILE FOR BUSINESS, BY A WATER-WORKS MAN.

BY F. F. FORBES, SUPERINTENDENT OF WATER WORKS, BROOKLINE, MASS.

[*Read January 8, 1908.*]

When, in December, 1906, it was proposed to procure an automobile for the use of the superintendent of the water department, the writer must confess that he had some misgivings as to the economic results which might be expected from the every-day use of such a machine.

One member of the water board in particular had had some experience with automobiles, and he was of the opinion that it would be for the benefit of the Water Department to own and operate an automobile, and his ideas in the matter received the hearty approval of the other members. The selection of a machine which would give the town the best service for a moderate outlay was not an easy problem to solve. After the usual preliminary work of looking over numerous catalogues and pamphlets gotten out by different manufacturers of automobiles, each one, of course, claiming that his machine was the best in the market, and personally examining different machines, the board decided to buy a 10 horse-power Cadillac runabout.

The price in Boston, including horn, lamps, and a few repair parts, was $794.00.

The results which have been obtained by one year's use of the automobile have been eminently satisfactory. It has been my custom to take the machine from the stable, where it was kept in the same building with the horses and wagons, every week-day morning and not return it to the stable necessarily until evening. If I spent one or more hours in the office, the machine was outside ready for immediate use.

At noon it was not necessary to feed it. The frequent calls here and there which all of us superintendents have could be made

in one half or perhaps one third the time required by a horse for motive power. I am very sure that two horses could not have done the work performed by our automobile during the busy months of the past season.

There is the further advantage that an automobile enables a superintendent to see more of the work under his charge and see it oftener, and also allows him more time for office duties. In fact, in my opinion, an automobile adds greatly to the efficiency of a superintendent.

An illustration of the time saved the writer on one day of each week can well be mentioned. On Monday it is one of the writer's duties to pay the men of the department, and he improves the time for an inspection of the pumping stations, the grounds around them, etc. The distance from the town hall is about seven miles — an hour's drive for a horse which is used every day, but an easy ride of twenty minutes with an auto, a saving of time in one half day of one hour and twenty minutes.

Perhaps some one will ask, How about all the delays caused by breakdowns, etc.? In reply I will say that in my opinion there is no more need of a breakdown or delay with an auto than there is when using a horse and wagon. During the whole of the past year, during which I have ridden over five thousand miles, I have not had one breakdown or delay of any account, and my automobile has never failed to bring me back to the stable on time with its own motive power at the close of the day's work.

It is particularly useful for night and Sunday calls. No horse to harness, but simply give a turn to the engine, jump into the automobile, and away at a speed of 20 or 30 miles per hour, provided, however, the police are not in sight, in which case a more moderate speed is advisable.

A few words in relation to the care of the machine and cost of maintenance may be of interest. Our stable man fills the tank with gasoline each day, usually in the morning, and sees that the oil and grease cups are full, and does the necessary washing. I have always made it a practice to examine the machine carefully once each day to see that the oiling devices are working properly and all the mechanical parts are in adjustment and repair. The tires will probably give one more trouble than anything else.

I always carry extra inner tubes in my automobile, as no one knows when a puncture may occur. I have been as long as three months without getting a puncture. The time required to replace an inner tube is about one-half hour, and after one knows how it is not a hard operation. The shoes, or tires, will last for a distance of from 3 000 to 5 000 miles, depending a good deal on the quality of the rubber in the shoes. I have worn out one set.

All must realize, however, that an automobile is a machine, and a rapidly running one at that, and consequently must receive the intelligent attention due all such mechanical devices. It is vitally important that all moving parts be kept well oiled and in good adjustment. For one who has some natural ideas of mechanics and is interested in mechanical matters this is not difficult or unpleasant and does not require much time.

The length of time required to learn to operate an automobile at slow speed need not be more than two or three days, but to feel as much at home behind the wheel at all speeds and in all places and act as mechanically as one does when walking, requires not less than four months of constant operating — at least, such has been my experience. It is a fact that one will learn little things about the machine nearly every day.

The maintenance of the automobile for twelve months has been as follows:

Repairs and extra parts	$58.18
Lubricating oil, 30 gallons	19.00
Gasoline, 330 gallons	71.15
Tires	113.40
Batteries and miscellaneous	9.68
Total	$271.41

In addition to the above expenses, it is necessary to have the machine carefully overhauled and painted once every year. This we find will cost from $75 to $100. The depreciation of the machine, supposing that at the end of four years its economic usefulness will end, will be $200 per year, making the total cost for one year $571.41. This amount gives a cost per day of $1.56.

It seems to the writer that, taking everything into consideration, it is greatly to the benefit of any water department, except

small ones, to use automobiles. The price per mile, about eleven cents, is less than the cost per mile when horses are used, and the saving in time is certainly an important item and in many cases worth more than the entire cost of operating the machine.

DISCUSSION.

Mr. Dexter Brackett.* I can say that the conditions on the Metropolitan Water Works are good, if not exceptional, for the use of automobiles to good advantage. From the limits of the Wachusett watershed in Princeton to the limits of the distribution system the distance is over seventy miles, and the distance across the district supplied with water is 20 miles. An inspection of the reservoirs and aqueducts, on account of the long distances, can be very greatly facilitated by the use of an automobile. I have used one on the work for four years, and there are now three machines of different makes in use on different parts of the works. Taking into consideration the saving in labor on account of the additional work which can be accomplished, there is, in my opinion, no doubt that they are a very valuable addition to almost any water-works plant.

As to the expense of operation, our experience has been that a light runabout operated almost constantly excepting during the winter can be expected to do good service for about three years at a cost of about $600 per annum, including first cost of the machine as well as repairs and supplies. The cost of repairs and supplies on the different machines has been from $200 to $450 per annum. As to the reliability of an automobile, much depends upon the care given to see that it is kept in good order. When I start on an all-day trip with a definite timetable I am very seldom delayed by the breaking down of the automobile. The only delay during the past season in riding between 4 000 and 5 000 miles, due to the automobile, was one of twenty minutes caused by a punctured tire.

Mr. Wm. F. Sullivan.† Mr. President, I agree with Mr. Forbes that the Cadillac is the best machine made, because I happen to have one this year. [Laughter.] In regard to breakdowns, we never had a breakdown; the only time it ever balked was when I

* Chief Engineer Metropolitan Water Works, Boston, Mass.
† Superintendent Pennichuck Water Company, Nashua, N. H.

had a hoodoo from this Association with me, a gentleman from the Builders' Iron Foundry. [Laughter.] The machine ran 2 300 miles to October 1, and it never failed to come back. We have never been "towed in." In addition to the usual work, our emergency man uses it for "hurry calls," and at night in answering alarms for fire.

We supposed that the overhauling was to be done by our engineer at the Pumping Station, but no such work has been necessary up to the present time. We reckon it is a great time saver because it gives us an opportunity to use the time usually consumed in going the rounds with a horse for other things.

I have here a few figures in regard to the cost of investment, and the economy of the automobile, that one of my friends wanted. The total cost of Cadillac (runabout) automobile, including top, lights, horn, gas tank, and 120-gallon Bowser gasoline storage tank and pump, was $1 084.98. For the maintenance of it last year we paid for gasoline, $25.14; cylinder oil, $4.35; grease, 20 cents; spindle oil, 30 cents; repairs on tires, $19.55; sundries, $1.65. The total expenditure was $51.19. Total mileage was 2 300. The cost per mile, $0.022. The mileage per gallon of gasoline, 17.7.

THE ACTION OF WATER ON PIPES.

BY FREELAND HOWE, JR., CHEMIST AND BACTERIOLOGIST, NORWAY, MAINE.

[*Read January 8, 1908.*]

It is the purpose of this paper to treat of the causes, extent, and results of, and the remedies for the action of water upon pipes. **Scope of Paper**

The subject is one of great importance and one which is not fully understood. Recent chemical research seems to throw new light upon the whole matter although the researches to which I refer present no really new theories, but furnish evidence substantiating principles which are clearly set forth in modern treatises on chemistry. The principal researches to which I refer are:

First. "The Corrosion of Iron," by Allerton S. Cushman, Washington, 1907. **New Light on Action**

Second. "The Corrosion of Iron and Steel," by Wm. H. Walker, *et als.* *Jour. Am. Chem. Soc.*, September, 1907.

Third. "Ionization of Water," by C. W. Kanolt. *Jour. Am. Chem. Soc.*, October, 1907.

As stated, the facts developed in these studies furnish confirmatory evidence to the principles of chemistry as given in modern works. In a trade publication which I wrote two years ago for the Pittsburg Filter Manufacturing Company, I ascribed the action of water on pipes to the same principles which these researches confirm.

Water pipes have been so extensively and seriously acted upon by the water which they convey as to cause the water to produce disease and death; water supplies to be abandoned and new ones sought; bursting of water pipes and failure of water pressure; complete replacement of considerable lengths of pipes; and to render the water unfit for drinking, washing, and various other purposes. The extent to which the action can go under certain circumstances is almost without limit and is dependent upon the **Extent and Result Action**

conditions under which the action takes place. For these reasons the subject is one of great interest to all who are associated with water works.

There are important questions constantly arising as to what kinds of pipes are best adapted to certain kinds of water. Some waters affect a pipe of one quality while others do not. In many places nearly all metal pipes are seriously affected. The effect which water has upon pipes has been ascribed to various causes, *e.g.*, oxidation, abrasion, corrosion, tuberculation, electrolysis, action of carbonic acid, peroxide of hydrogen, biological activity, etc. There is a great medley of causes to which this action is referred. It is difficult to determine where one process leaves off and another begins. Is there one cause for this action or are there many? What is the exact truth regarding this action? To what extent will the action proceed? Is there any remedy or preventive? All these questions deserve serious consideration.

Problem Stated

For a solution of the problem it is necessary to know:

First, what *water* is; *second*, what *pipes* are; and *third*, what *action* is.

Dissociation

In order to arrive at a full understanding of the action of water on pipes, I consider it necessary to know what *dissociation* is. It is this: Water is made up of two atoms of hydrogen and one of oxygen. It is H_2O. There never has been, is not now, and probably never will be, any absolutely pure H_2O. Distilled water is an approximation to this, but distilled water dissociates slightly to form hydrogen ions (hydrion) and hydroxyl ions (hydroxidion); that is: $H_2O = H^{\cdot} + OH'$. This is dissociation, or one kind of it. Likewise all substances which go into solution in water dissociate to a greater or less extent, *i.e.*, split up into their component parts. Common salt (sodium chloride) dissociates to form its components, chlorine ions (chloridion) and sodium ions (sodion). The products of dissociation are termed *ions* and have properties different from the chemical elements from which they are derived. The dissociation of chemical substances is usually slight, and the weaker the solution the more complete the dissociation. Suppose we start with salt and water. If we put into the water more salt than will dissolve we have this combination, solid salt (sodium chloride), salt in solution, and dissociated salt giving rise to sodium

and chlorine ions (sodion and chloridion). The sodion is different from sodium, which is a metal, and the chloridion different from chlorine, which is a gas. The exact degree and manner of dissociation of all substances does not concern us here, but it does interest us to know that it is only when substances are dissociated into their component ions that they are most active chemically.

It happens that natural waters contain nearly all salts in such a low degree of concentration that they are completely dissociated or nearly so and hence are very active chemically. The quantity and quality of the ions determine to a large extent the action of the water on pipes.

Dissociation of Water

Kanolt, summarizing his own work and that of others working on the same subject before him, gives the following table showing the extent of the dissociation of water.

Table showing the Hydrogen Ion Concentration ($\times 10^7$) in Pure Water. Results of Various Investigations.

Investigator.	0°.	18°.	25°.
Arrhenius			1.1
Wijs			1.2
Nernst		0.8	
Löwenherz			1.19
Kohlrausch and Heydweiller	0.36	0.80	1.06
Kanolt	0.30	0.68	0.91

This means that at 0° one million liters contains 30 mg. of hydrogen ions and 510 mg. of hydroxyl ions; at 18°, 68 mg. of hydrogen ions and 116 mg. hydroxyl ions; at 25°, 91 mg. of hydrogen ions and 155 mg. hydroxyl ions. Without exception these quantities are smaller than those in which any elements of water are usually determined in making a sanitary or mineral analysis, and yet they are large enough to cause water to have a decided action toward metals. (*Cf.* Rept. St. Bd. Health, Mass., 1898.) Clark found that distilled water with exclusion of air dissolved 0.77 parts per million of lead in two weeks. Walker obtained similar results. I will defer the detailed interpretation till later. It is merely desired at this point to understand what dissociation is and to what extent it occurs in water — as pure as we can make it — distilled water. On account of its dissociation water can be regarded as either a weak acid or a weak base.

Carbon Dioxide

To a further understanding of the action of water on pipes I consider a detailed knowledge of "carbonic acid" of utmost importance. The chemical formula of carbonic acid is H_2CO_3, but no one has ever had this in his possession and probably never will, for it is, up to date, a hypothetical substance. It is merely a product of thought. Many chemists in the analysis of water determine the amount of "carbonic acid expressed as CO_2" (carbon dioxide). The Maine State Board of Health and Massachusetts State Board of Health do not consider the determination of this constituent of water of sufficient importance to record it in the regular analyses which they make of the public water supplies.

Method of Analysis

The determination for carbon dioxide is usually made by titrating 100 cc. of a freshly collected sample against fiftieth normal sodium carbonate, using phenolphthalein as an indicator. In this titration the reaction is as follows: In the first place the sodium carbonate dissociates or hydrolyzes so:

$$Na_2CO_3 + H_2O = 2Na^{\cdot} + 2OH' + CO_2,$$

which means that the sodium carbonate hydrolyzes to form sodion, hydroxidion, and carbon dioxide (a gas). Hydroxidion will form a chemical union with phenolphthalein to produce a compound which imparts to water a red color; but if the water happens to contain hydrion, this hydroxidion will unite with it to form water so:

$$OH' + H^{\cdot} = H_2O.$$

This reaction will take place as long as there is any hydrion left, when an excess of hydroxidion will remain and the pink color showing the end point will prevail.

The equation is usually written:

$$Na_2CO_3 + H_2CO_3 + H_2O = 2NaOH + H_2O + 2CO_2,$$

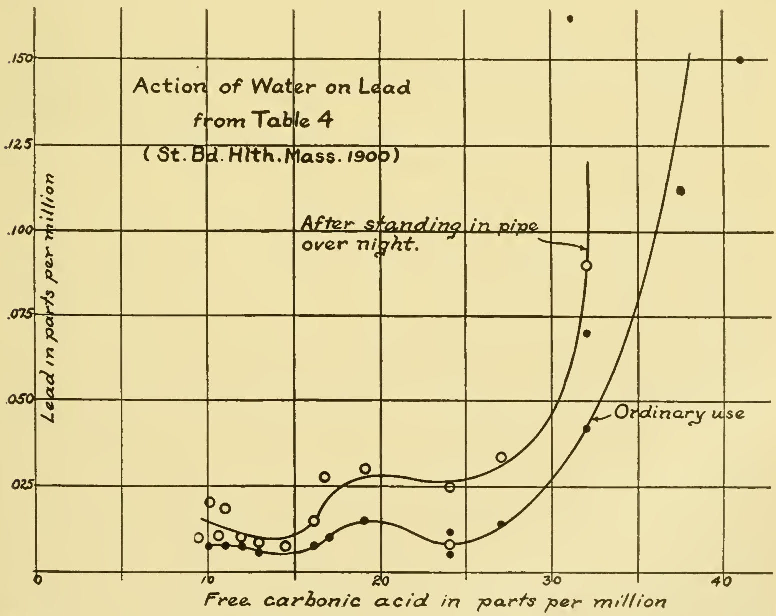
and the results are expressed as parts per million of CO_2. Usually the figures do show the exact number of parts of carbon dioxide present in the water, although this does not enter directly into the reaction by means of which its quantity is determined. The proper equation is:

$$2Na^{\cdot} + 2OH' + CO_2 + H^{\cdot} + HCO_3' = 2Na^{\cdot} + 2OH' + 2CO_2 + H_2O.$$

What actually happens is that the hydroxidion derived by hydrolysis from the sodium carbonate solution combines with the hydrion to form water. The hydrion is what gives water its acidity and it exists in the water by virtue of the presence of its partner (so to say), carbon dioxide. Its partner might as well be something else, in which case the analysis would erroneously show the presence of carbon dioxide.

The pressure of one atmosphere is fifteen pounds per square inch. Under this condition one liter of water will dissolve, at 60°, 580 mg. of CO_2. Under greater pressure water will dissolve more gas, the amount dissolved at any given number of atmospheres being about as many times as great as there are atmospheres pressure.

The accompanying diagram made from data contained in the 1898 report of the State Board of Health of Massachusetts shows that there is a direct correlation between the amount of carbonic acid present in water and the degree of action on lead pipe.



The new light in which I wish you to look at "carbon dioxide" is this: That while in the majority of cases there is present in a Significance of Analysis

water the same amount of carbon dioxide as the analysis indicates, the active principle which we determine in the water by analysis is the *hydrogen ion;* that this is what reacts with our chemical reagent, and that we merely assume the presence of the proper amount of CO_2 to allow the hydrion to be in the water. The correlation which the above diagram indicates is due, as we shall see later, to the action of the hydrion and not the CO_2.

Natural Occurrence Almost every natural water contains some hydrogen ions, *i.e.*, is acid to phenolphthalein. Even rain water may be so. Surface water is still more so than rain water owing to the production of hydrogen ions and their complements in the soil and their extraction therefrom by the running water. Ground water is generally more acid to phenolphthalein than surface water for two principal reasons; first, that this water is longer in contact with the soil; and second, that being under more pressure, it can hold more hydrion and carbon dioxide.

Water a System In arriving at an understanding of the action of water on pipes it is necessary to know what *water* is. My understanding of what water is may be a little different from that of some others. I understand water to be what chemists call a *system.* A chemical system is a collection of various elements or *components* which are each and all infinitely related to and dependent upon the others. The quantities of *some* components are dependent upon the quantities of others, and *some* cannot exist in the system unless others are there.

A Chemical System

Different Systems There are many different kinds of systems. Each is made up of an almost infinite number and kind of parts or elements, each and every one of which is dependent upon each and every other one. Each holds its place by virtue of the presence and deportment of all the rest. If one new element enters or leaves a system another one must come to or go from it in order to balance it. The natural tendency in every system is to maintain itself, *i.e.*, to preserve an equilibrium.

A Water System I speak of *water* as a *system, i.e.*, H_2O, the carbonates, chlorine, magnesium, potassium, etc. Each element of the system is a *component.* As in the water-works system, so in the water system, a new element may enter naturally or artificially, and at the same time there leaves a certain other element or elements which results in the improvement or impoverishment of the system as applied to

man's various uses. These analogies might be carried indefinitely, but we have other considerations.

Let us now see of what a typical water system is composed, or what its components are.

To this end we will start with water vapor which forms by evaporation from the surface of terrestrial bodies of water, from green leaves, etc. This vapor consists of hydrogen and oxygen and is invisible. It may become condensed and so visible in the form of clouds or fog. If condensed it consists of drops of water (H_2O) and in its passage through the air comes in contact with various substances for which it has a greater or less affinity. This water itself becomes dissociated, as before explained, both from the nature of the water itself and as a result of the action of ultra-violet light. This gives us, to start with: **Water Vapor**

$$2H_2O = H^{\cdot} + OH' + H_2O.$$

(hydrion, hydroxidion and water.)

This water comes in contact with carbon dioxide (CO_2), a gas present in air to the extent of about one volume in 2 500 of air. This would give us:

$$3H_2O + CO_2 = H_2O + H^{\cdot} + OH' + H^{\cdot} + \underbrace{HCO_3'}_{\text{hydrocarbanion, the new element}}.$$

Carbon dioxide gas is derived from various sources, among which are natural processes of decay, animal exhalations, and artificial combustion.

Other substances in the air which may become associated with our system are ammonia gas, nitric acid, oxygen, ozone, organic matter, dust particles (consisting of sea salt and many other light substances).

It has been found that 100 volumes of water under a pressure of one atmosphere will absorb the following volumes of gas:

	Oxygen.	Nitrogen.	Hydrogen.	Carbon dioxide.	Carbon monoxide.	Nitrous oxide.	Hydrogen sulphide.	Sulphur trioxide.	Marsh gas.	Ammonia.	Nitrogen trioxide.
0°	4.82	2.35	2.15	179.7	3.54	130.5	437.1	688.6	5.4	104960	7.38
20°	3.10	1.54	1.83	90.1	2.32	67.0	290.5	362.6	3.5	65400	4.71

As a result of contact with all these substances meteoric water may constitute a very complex system, as for example:

$$H_2O + 2H^{\cdot} + OH' + HCO_3' + Na^{\cdot} + Cl' + 3NH_3^{\cdot} + 2SO_4'' + Ca^{\cdot\cdot} + NO_3' + N + O_2, \text{ etc.}$$

Analyses of rain water show all these components present and to such an extent that the amount of solid matter obtained from rain water has been known to be as much as 50 gm. per cubic meter.

Surface Water

This water falling to the ground at once attaches to itself whatever substance it may come in contact with and which by its nature it may take up. Some of the elements already present may be precipitated in the soil or may be taken up by the various plants inhabiting the soil, such as molds, bacteria, mosses, ferns, grass, shrubs, trees, etc. Whatever changes do take place are very complex and it would take more than one lifetime to attempt to solve completely the exchange of elements which takes place here. As a general rule it may be said, however, that surface water contains more dissolved substances than meteoric water, although the reverse may be true.

Ground Water

A new factor which the water encounters in passing into the ground is pressure. Increased pressure allows the water to absorb more of certain elements than when it is under a pressure of only one atmosphere. Whether surface or ground water, the system comes in contact with more metals and salts and has its composition changed according to the geological and climatological conditions which pertain.

It is principally with surface and ground water that we are now interested, and the problems which confront us in studying the action of water upon pipes is wholly dependent on the character and quantity of the components of the system which this water forms.

What Pipes are

Having come to a knowledge of *what water is,* we will ask *what pipes are.* Pipes are of metal (more or less pure): iron, plain or zinc coated (galvanized), tin or lead lined; brass (copper and zinc); lead; block tin; copper; glass; wood; and cement or cement lined. Some pipes have internal and external coatings which prevent immediate contact of water and metal (more or less). These coatings may be imperfect on account of blow holes, scratches, etc. The metal of some pipes is impure, which might

cause galvanic action. Sometimes pipes of one metal are joined by means of another, which might also institute galvanic action.

Pipes then are mainly of metal, and in dealing with the action of water on pipes we have to do principally with the action of water on metals.

Potential Series of the Metals

By experimenting with different substances it has been found possible to arrange all the metals in what is called an *Electrochemical Series,* so that each precipitates all the metals following from their aqueous solutions and is in turn precipitated by each of the preceding ones. This series is also called the *Potential Series of the Metals* and is in part as follows:

Potassium	Cobalt
Sodium	Nickel
Calcium	Tin
Magnesium	Lead
Aluminum	Hydrogen
Manganese	Copper
Zinc	Silver
Iron	Platinum

Characteristics of the Metals

We have in this potential series of the elements an arrangement of the metals in the order in which they are dissolved in water in the greatest quantities and with the greatest energy, and, in a general way, a list of the metals in the opposite order of their degree of poisonous qualities. At one end of the series is sodium, which attacks water very violently, and at the other end is platinum, which chemists find almost indispensible in the laboratory because it is so resistant to all kinds of liquid. Zinc and iron occur in water in greatest quantity, but never enough, so far as known, to be poisonous, while the ions of lead, tin, copper, and silver are all poisonous.

If we have a system containing calcium, zinc, iron, and lead, metallic sodium will precipitate these from solution, *i.e.,* will replace them in the system. They will be converted into an insoluble form.

The metals throughout are characterized in that they receive only positive electrical charges; or they are able to go into solution only in the form of positive ions. The tendency which metals have of going into solution in this way is called the *Solution*

Pressure and has a definite value for each metal under definite conditions. In order to determine then in a definite way if any system of water with which we have to deal will act upon any of the metals of which pipes are composed, it is necessary to know the nature of the metals and also the nature of the system. A shorter way is to put the two together and determine by analysis if action does take place. But sometimes this is an expensive operation, and even then we are not sure whether the action, if present, will be permanent. It is desirable to have as complete a knowledge as possible of all conditions.

Mode of Action

Metals replace Hydrion

How, now, do different waters act upon the metals of pipes? We have seen that hydrogen ions are almost universally present in natural waters and even in distilled water, and we also observe that hydrogen has a place in the potential series of the metals which would allow it to be replaced by nearly all of the metals of which pipes are made, viz., zinc, iron, tin, and lead; and this is exactly what does take place in almost all cases where pipes are acted upon. When hydrion is present in water under proper conditions it will be displaced by any of the metals named and will itself become converted into inactive gaseous hydrogen and escape from the water if possible.

Copper

Copper occurs in the series after hydrogen, which would lead us to suppose that it cannot replace hydrogen. This is true and shows the reason why copper is particularly adapted for water conductors.

Silver

Silver occupies a position in the series which makes it affected still less than copper. This fact is taken advantage of in some cases, *e.g.*, at Poland Springs, Maine, where a silver-lined pump and connections are being built for use in connection with Hiram Ricker & Sons' beautiful bottling establishment.

The following table is prepared from the records of the Massachusetts State Board of Health. It shows that different waters, each acting under the same conditions, affect zinc most, iron next, and lead and tin least. The figures show averages:

PARTS PER MILLION DISSOLVED.

	Zinc.	Iron.	Lead.	Tin.
Fairhaven	9.7	4.7	2.0	0.2
Kingston	4.5	0.05	2.5	0.19
Lowell	5.6		0.4	0.09
New Bedford	5.1	1.9	1.6	0.25
(Time of action, one hour)				
Fairhaven	15.4	9.2	4.0	0.4
(Time of action, over night)				

In the case of zinc and iron, the difference is plain; but there seems to be less tin than lead dissolved, a fact which is of general prevalence. The reason probably is that tin does not form powerful bases; that at ordinary temperatures it does not oxidize, while lead oxidizes easily at low temperatures. Zinc, which is the pipe metal farthest removed from hydrogen, acts most strongly, and iron next. Lead and tin are close together, near hydrogen, and have a less solvent action. Lead oxide is slightly soluble in water and communicates an alkaline reaction to it since it forms hydroxidion.

Apparent Exceptions

That copper is not acted upon by natural waters like other metals is due to two things: *first,* its place in the potential series of the metals; and *second,* that in many natural waters a protective coating is rapidly formed over the surface. That metallic copper does react with water has been demonstrated in the case of the investigations in relation to the sterilization of waters, but here it does not act like other metals. A reduction product of some anion present in the water is formed something like:

Copper

$$3Cu + 8H^{\cdot} + 8NO_3' = {}_3Cu^{\cdot\cdot} + 6NO_3' + 2NO + 4H_2O;$$

$$\text{or, } Cu + 4H^{\cdot} + 2SO_4'' = Cu^{\cdot\cdot} + SO_4'' + SO_2 + 2H_2O.$$

Lead

Another apparent exception to the statements herein made is in the case where a water containing an excess of lime, and, therefore, no hydrion, has a decided solvent action on lead pipes, a condition which Fuller reports during the experimental work at Cincinnati. In this case also the lead probably goes into solution as part of an anion which, on concentration, would form a plumbate in the same way that aluminum with sodium hydroxide forms an aluminate.

$$Pb + Ca^{\cdot\cdot} + 2OH' = Ca^{\cdot\cdot} + PbO_2'' + H_2.$$

This of course is an artificial condition and one not often met with except in the case of softening or " lime and iron " plants.

Mr. Fuller does not explain the reaction nor does he state how the lead went into solution, but in all probability it was as an anion as stated, either PbO_2'' or $HPbO_2'$.

Role of Oxygen

Thus far in my discussion I have not alluded to the action of oxygen, which is generally considered the all-important factor in the action of water on pipes. Walker *et als.*, in their study on the Corrosion of Iron and Steel, concluded among other things that the primary function of oxygen in the corrosion of iron is in depolarizing those cathodic portions of the iron upon which the hydrogen tends to precipitate and that it acts only secondarily to oxidize ferrous to ferric iron. This means that in the absence of oxygen (an extremely unnatural condition) there would be a tendency to polarization in a quiet water which would act as a preventive to the further formation of hydrogen gas and a concomitant retardation to the solution of a metal. Without doubt the low degree of action which Clark found when lead was placed in distilled water with exclusion of air was due to the same cause.

Electrolysis

In the case of electrolysis of pipes the metal is dissolved in exactly the way described above, but the action is accelerated by the action of the electric current which tends to drive the metals into solution at the point or points where the current leaves the pipe to enter the water — whether inside the pipe or out. Investigations are under way to determine the extent of corrosion of pipes in moist soils so that we may know how much of the corrosion is natural (so to say) and how much induced by the action of stray currents from electric railways, etc.

Conditions affecting Solution of Metals

Other conditions which tend to increase or retard the action of water on pipes are temperature, pressure, concentration of salts, amount of organic matter, etc. Increase in any of these factors tends to increase the action of water on pipes except in such cases as where the salts in solution unite with the metals to form insoluble compounds which deposit on the pipes to form coatings through which the water cannot act. Such coatings form chiefly on lead and copper pipes and are very effectual in preventing the solution of the metal of the pipe.

Forms of Action

The explanations given above embrace practically all forms of action which water has upon pipes. This action is described under various names: corrosion or eating away; pitting, formation of

depressions; electrolysis, decomposition of a pipe by an electrical current; tuberculation, action accompanied by the formation of tubercules or limpets. All phenomena are due to one principal cause, — the solution of the metal. In all cases the metal replaces something in the water.

It matters not whether a pipe is laid through a stream (surrounded by water) or in moist soil; whether water passes through the pipe or outside of it. If the metal is exposed inside or out and the proper conditions prevail, action will result.

Aside from mechanical abrasion the method of action explains all natural and some artificial occurrences. The metal of the pipe, by virtue of its solution pressure, replaces the hydrogen ion occurring naturally in the water, and the hydrogen gas so formed escapes to the atmosphere if possible.

Remedial Measures

Now that we have taken so much time in arriving at an understanding of the action of water upon pipes, what does it all amount to? It amounts to this: that understanding what the elements concerned in the action are, and knowing what their properties are, we are so able to treat the water that their effect may be overcome. In one particular case I was the fifth chemist called in by a water company to determine their trouble. Every other one had pronounced the water of exceptional purity, but even then the water company were not able to make the consumers believe so. At the source the supply was of "exceptional purity," but the water had a powerful solvent action on iron pipes so that by the time it reached the consumers it not only contained large amounts of iron but had a very offensive odor and taste. An inexpensive method of removing the dissolving substance was found and the effect was so pronounced that the very next day after starting the apparatus every one in town remarked about the improved conditions and the water is now giving general satisfaction. Not one of the chemists preceding me had made a determination for even the presence of the element by virtue of which the water affected the pipes.

Knowing what the offending impurities in any water are, it is comparatively easy to know how they get there and so how to get them out. The case just cited was handled in the manner outlined above.

It is impossible to outline any method of procedure which will

furnish relief in all cases as no two are exactly alike, but in general it can be said that in most cases a simple aëration will accomplish remarkable results.

DISCUSSION.

THE PRESIDENT. This paper is now open for discussion.

MR. B. B. HODGMAN. Mr. President, I should like to ask Mr. Howe if it is the hydrogen ions that affect the iron.

MR. HOWE. The hydrogen ions, under proper conditions, are replaced by the iron metal of the pipe, in the case of an iron pipe.

MR. HODGMAN. Are the hydrogen ions found in waters which are very alkaline?

MR. HOWE. They occur in nearly all natural waters, even very alkaline waters.

MR. E. D. ELDREDGE. I would like to ask Mr. Howe if there is more rust on the pipes in summer — in high temperature — than in low temperature; if rust is present in greater quantities at one time of the year than another.

MR. HOWE. Usually in summer there is more carbon dioxide formed, the carbon dioxide being formed by the decomposition of vegetable matter, so that there is more of it to go into solution. But, on the other hand, the increased temperature will drive it from solution; just the same as when you boil water in a teakettle, or in any open vessel, the boiling process liberates all the carbon dioxide and with it the hydrogen ions which accompany it. That is the reason that boiled water is so much softer than water not boiled, — because the carbon dioxide and the accompanying hydrogen ion — or metal which has replaced it — is removed by the boiling process.

Briefly, in answer to your question, there is more carbon dioxide in summer to be dissolved, but the higher temperature will allow the solution of less. So the action in winter would be greater, because the decreased temperature allows more carbon dioxide, and the accompanying hydrogen ion, to go into solution, and so act upon the pipe.

MR. A. O. DOANE. I have noticed that hot water has a much more corrosive action upon pipes than cold water; hot water meters are very difficult to maintain. Now, I should like to ask

Mr. Howe to explain the more corrosive action of the hot water than the same water when it is cold.

Mr. Howe. Mr. President, it is almost impossible to discuss the subject upon general principles, because waters are so different; but in the presence of certain salts there would be a formation of hydrogen ions induced by heat which would not occur in other waters. That would be the case particularly in hard waters containing magnesia.

Mr. Doane. The particular case I had reference to was water in the Metropolitan District, which is not considered hard water, although I think almost all hot waters do affect the composition parts of meters more than cold waters.

Mr. Howe. Under heat the action of water is much greater than it is when water is cold. In a boiler the water is confined, so that these elements which affect the metals are not allowed to escape; and the action would be greater if the water were confined, as in a boiler, and also the pressure would increase the action.

Mr. G. E. Winslow. Mr. President, there have been a great many cases of lead poisoning from the water going through lead pipes; in the city of Waltham the pipes connecting the services with the mains are perhaps 18 or 20 inches long; I had occasion to take out a great many of them in years gone by, and in all cases I found them of a bright color inside. I would like to know what is the nature of the action of the water on that lead which might cause lead poisoning.

Mr. Howe. In answer to the gentleman's question I will say that in waters which naturally contain one grain per gallon of substances determined as carbonates, there is usually formed a coating over the lead which prevents further action of the water upon the pipe. In the case of distilled water, Mr. Clark found, in his work, "The Action of Water upon Metals," that a very much larger amount of lead was dissolved by distilled water than by water which contained a small quantity of dissolved salts. And the reason for that is, as stated, that a portion of the salts combines with the lead to form an insoluble lead salt, which joins with the lead pipe and prevents further action by the water. The lead is protected to a considerable extent by the formation of this insoluble lead salt on the pipe.

MR. S. H. MCKENZIE. I should like to inquire if an ordinary soft surface water would contain more than that one grain per gallon of carbonate just spoken of.

MR. HOWE. Some waters, Mr. President, contain much less than one grain per gallon, or 17 parts per million, particularly in our granite regions of New England; but usually nearly all waters contain that much; there are exceptions, however.

MR. MCKENZIE. If the water contained less than one grain of carbonate per gallon, would it be detrimental to the consumer?

MR. HOWE. In general terms, yes, that water would have an action upon lead pipe.

MR. MCKENZIE. If, in removing the goose neck, you find a sort of slimy coating upon the inside, would you say that lead had been coated over?

MR. HOWE. This coating usually has considerable substance to it; the carbonate usually has more consistency. The slimy coating might be something else, or else it might be hydroxide. It would be impossible to tell without examination.

MR. E. B. PHELPS. Mr. President, there is one aspect of this question which Mr. Howe just alluded to; that is, the possibility of action where two metals are coupled up in the same pipe system. I have recently been in the middle West, where there is an alkaline water which, according to Mr. Howe's theories, ought not to have great solvent action, but this water has very serious solvent action upon galvanized iron pipe, and the trouble is traced to the very common use of brass pipe in the faucets.

THE PRESIDENT. Is there anything further to be said?

MR. FULLER. I should like to ask Mr. Howe for just a word with regard to the use of galvanized iron pipe for service pipes, or for use in houses, as to their desirability for conveying water.

MR. HOWE. It depends entirely upon the composition of the water.

MR. FULLER. Take a ground water, Mr. Howe, for instance.

MR. HOWE. Ground water affects all pipes, generally, more than surface water; of course it contains more of this active element. In other ways it would affect the pipes less, on account of the presence of more salts which would exist to form protective coatings. An exact knowledge of a definite place must be had in order to pass definite judgment.

PROCEEDINGS.

Annual Meeting.

Hotel Brunswick,
Boston, January 8, 1908.

The President, Mr. John C. Whitney, in the chair.

The following members and guests were present:

Honorary Member.

F. W. Shepperd. — 1.

Members.

S. A. Agnew, C. H. Baldwin, L. M. Bancroft, H. K. Barrows, G. W. Batchelder, J. E. Beals, A. F. Ballou, J. W. Blackmer, George Bowers, Dexter Brackett, E. C. Brooks, James Burnie, George Cassell, J. C. Chase, C. E. Childs, H. W. Clark, F. L. Clapp, R. C. P. Coggeshall, M. F. Collins, J. W. Crawford, J. H. Child, A. W. Cuddeback, L. E. Daboll, A. O. Doane, E. D. Eldredge, I. T. Farnham, J. H. Flynn, F. F. Forbes, W. E. Foss, A. N. French, F. L. Fuller, H. M. Geer, J. A. Gould, F. J. Gifford, R. A. Hale, F. E. Hall, T. G. Hazard, Jr., D. A. Heffernan, B. B. Hodgman, H. G. Holden, Freeland Howe, Jr., C. L. Howes, W. S. Johnson, J. W. Kay, Willard Kent, F. C. Kimball, G. A. King, E. S. Larned, S. H. McKenzie, Thomas McKenzie, N. A. McMillen, A. E. Martin, John Mayo, J. F. Moore, C. A. Mixer, O. E. Parks, W. W. Patch, H. E. Royce, H. W. Sanderson, P. R. Sanders, E. M. Shedd, C. W. Sherman, J. Waldo Smith, G. H. Snell, G. A. Stacy, G. T. Staples, J. T. Stevens, W. M. Stone, W. F. Sullivan, H. L. Thomas, R. J. Thomas, W. H. Thomas, D. N. Tower, C. A. Townsend, W. H. Vaughn, J. C. Whitney, L. J. Wilber, F. B. Wilkins, H. B. Wood. — 79.

Associates.

Anderson Coupling Company, by Charles E. Pratt and F. A. Leavitt; Harold L. Bond & Co., by Harold L. Bond; Builders Iron Foundry, by A. B. Coulters; Chapman Valve Manufacturing Company, by Edward F. Hughes; The Fairbanks Company, by George H. Gray; Hersey Manufacturing Company, by Walter A. Hersey; International Steam Pump Company, by Samuel Harrison; Lead Lined Iron Pipe Company, by T. E. Dwyer; Ludlow Valve

Manufacturing Company by, H. F. Gould; National Meter Company, by C. H. Baldwin, J. G. Lufkin, and H. L. Weston; National Water Main Cleaning Company, by B. B. Hodgman; Neptune Meter Company, by Fred A. Smith and H. H. Kinsey; Norwood Engineering Company, by H. W. Hosford; Platts Iron Works Company, by F. H. Hayes; Rensselaer Manufacturing Company, by C. L. Brown and F. S. Bates; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by E. M. Shedd; Chas. Millar & Son Company, by Charles F. Glavin; Union Water Meter Company, by F. E. Hall; Water Works Equipment Company, by W. H. Van Winkle; R. D. Wood & Co., by W. F. Woodburn, Harry Crowther, and H. A. Jensennius. — 28.

Guests.

James G. Hill, water commissioner, Dr. T. T. Carroll, Lowell, Mass.; L. R. Washburn and William E. Smith, members Water Board, New Bedford, Mass.; A. E. Blackmer, superintendent water works, Plymouth, Mass.; Joseph Weeks, Bridgewater, Mass.; Horace Mitchell, Kittery Point, Me.; J. J. Ryan, foreman water works, Southington, Conn.; D. W. McCormo, Panama; Mr. A. C. Horn, New York City; L. H. Camfel and Charles R. Gow, Boston, Mass. — 12.

At the close of the dinner the meeting was called to order by President Whitney, who said:

President's Address.

Gentlemen of the New England Water Works Association, — Again we meet to review briefly the work of the year just passed, the twenty-fifth in the history of our Association.

Since the last report we have to record the death of six members:

Lewis P. Collins, ex-mayor of Lawrence, Mass., elected a member December 12, 1894.

Myron Edward Evans, C. E., New York City, president of the Cape Breton Railway, elected a member June 13, 1900.

Valentine C. Hastings, superintendent of the Concord, N. H., water works, a member since June 10, 1886.

Arthur J. L. Loretz, M. E., New York City, elected to membership December 9, 1896.

James W. Locke, general foreman water works, Brockton, Mass., a member since January 9, 1895.

John F. J. Mulhall, Boston, Mass., water-works accountant and treasurer of several water companies, elected to membership November 14, 1900.

Mr. Hastings had served on various committees, had twice been vice-president, took an active interest in the Association, and his loss was deeply felt. He had been superintendent at Concord, N. H., for thirty-four years.

Our total membership is now 702, a gain for the year of 18. It should, perhaps, be emphasized that this membership is absolutely net, all whose assessments were overdue having been dropped from the rolls.

The rate of growth seems fairly satisfactory until we attempt to analyze our membership, when we discover that over 40 per cent. of New England municipalities having a population in excess of 3 000 are not represented in this Association.

These figures open before our vision a broad, fruitful field for missionary work; we know that membership in our Association would benefit every one of these outsiders; we believe that each one would bring something of value to our meetings.

The first president of our Association in his address recommended that each city and town assume the expense incurred in attending these meetings, as the knowledge obtained was of direct benefit to the municipality, and it may further be said that the water-works official who is neither a member of this Association nor a subscriber to the JOURNAL is handicapped in the administration of his plant.

We are to be congratulated on our financial condition. After paying all bills there is a treasury balance of over $4 000, a substantial increase over 1906, and more than double the amount possessed by the Association six years ago.

The JOURNAL, of which we all are proud, speaks for the intelligent, discriminating work of the Editor. Particular mention should be made of the water-works statistics printed in the September number. It is but a simple statement of fact to say that this invaluable publication is still improving.

Mr. Sherman has also brought up to date a table appearing first in 1902, and which at this time is of special interest as showing, with other information, the progress of the Association during the twenty-five years of its existence.

NEW ENGLAND WATER WORKS ASSOCIATION.

Year.	President.	Membership at End of Year.				Annual Convention.		Receipts.	Expenditures.	Cash Balance.
		Members.	Associate.	Honorary.	Total.	Place.	Date.			
1882	(Organized)	27	—	—	27	Boston, Mass.	June 21, '82			
1882–3	*James W. Lyon	37	6	—	43	Worcester, Mass.	June 21, '83	$245.00	$87.86	$157.14
1883–4	Frank E. Hall	48	9	—	57	Lowell, Mass.	June 19–20, '84	156.14	171.90	141.38
1884–5	*George A. Ellis	83	44	—	127	Springfield, Mass.	June 18–19, '85	651.84	511.44	281.78
1885–6	R. C. P. Coggeshall	106	47	—	153	New Bedford, Mass.	June 16–18, '86	1 658.50	1 643.42	296.86
1886–7	*Henry W. Rogers	137	52	2	191	Manchester, N. H.	June 15–17, '87	1 342.28	1 066.98	572.16
1887–8	*Edwin Darling	181	54	3	238	Providence, R. I.	June 13–15, '88	2 013.30	1 697.15	888.31
1888–9	*Hiram Nevons	209	64	4	277	Fall River, Mass.	June 12–14, '89	2 204.07	2 127.70	964.68
1889–90	Dexter Brackett	257	73	5	335	Portland, Me.	June 11–13, '90	2 511.27	2 346.65	1 129.30
1890–1	*Albert F. Noyes	281	74	5	360	Hartford, Conn.	June 10–12, '91	3 055.13	1 884.78	2 299.65
1891–2	Horace G. Holden	290	70	5	365	Holyoke, Mass.	June 8–10, '92	2 887.17	3 278.54	1 908.28
1892–3	George F. Chace	338	69	5	412	Worcester, Mass.	June 14–16, '93	3 422.61	3 317.22	2 013.67
1893–4	*Geo. E. Batchelder	365	73	5	443	Boston, Mass.	June 14–16, '94	3 208.85	3 259.07	1 963.45
1894–5	George A. Stacy	401	81	5	487	Burlington, Vt.	Sept. 11–13, '95	3 147.41	3 115.99	2 673.03
1895–6	Desmond FitzGerald	442	82	5	529	Lynn, Mass.	June 10–12, '96	3 179.91	3 148.49	2 704.45
1896–7	*John C. Haskell	464	80	5	549	Newport, R. I.	Sept. 8–10, '97	3 340.23	3 322.94	2 721.74
1897–8	Willard Kent	488	77	5	570	Portsmouth, N. H.	Sept. 14–16, '98	3 002.13	2 786.95	2 936.92
1898–9	Fayette F. Forbes	494	73	5	572	Syracuse, N. Y.	Sept. 13–15, '99	2 825.71	3 050.23	2 712.40
1899–1900	Byron I. Cook	519	70	5	594	Rutland, Vt.	Sept. 19–20, '00	4 920.49	5 524.65	2 108.24
1901	Frank H. Crandall	493	58	4	555	Portland, Me.	Sept. 18–20, '01	4 238.55	4 283.22	2 063.57
1902	Frank E. Merrill	522	60	5	587	Boston, Mass.	Sept. 10–12, '02	5 158.48	4 680.32	2 541.73
1903	Charles K. Walker	520	55	3	586	Montreal, Canada	Sept. 9–11, '03	5 032.40	4 505.08	3 069.05
1904	Edwin C. Brooks	538	58	8	604	Holyoke, Mass.	Sept. 14–16, '04	5 328.31	5 528.21	2 869.15
1905	George Bowers	584	53	8	645	New York, N. Y.	Sept. 13–16, '05	5 431.16	5 411.58	2 888.73
1906	Wm. T. Sedgwick	618	51	15	684	White Mts., N. H.	Sept. 12–14, '06	5 366.94	4 845.14	3 410.53
1907	John C. Whitney	636	51	15	702	Springfield, Mass.	Sept. 11–13, '07	5 291.83	†4 222.06	4 480.30

* Deceased. † Not including December JOURNAL and reprints.

The usual winter meetings have been held and were well attended; papers proved interesting and were thoroughly discussed.

Special mention should be made of the paper by Mr. William S. Johnson given at the March meeting, " Some New Facts Relating to the Effect of Meters on the Consumption of Water." His view of the subject was from a somewhat unusual standpoint and brought out so full a discussion that the paper, with accompanying comments, filled the June number of the JOURNAL.

In June we had a trip to Gloucester, going by steamer and returning by train, with a shore dinner in Gloucester and a trolley trip " around the Cape."

The annual convention at Springfield in September was a success in every way. Attendance was large, papers interesting, hotel accommodations satisfactory, a well-managed exhibition of water-works appliances, and on the last day a visit to the Springfield filtration plant at Ludlow, and, through the courtesy of the Chapman Valve Manufacturing Company, an opportunity to inspect their works and to partake of luncheon which they kindly provided.

At Springfield, largely due to papers read on " Water Rights " and " Value of Water Powers," with the discussion which followed, it was

Voted: " That a committee of five be appointed by the President to collect data relating to awards that have been made for damages resulting from the diversion of water; also to consider the practicability of joint action with the National Cotton Manufacturers' Association or other organization of mill owners, leading to the formulating of standard rules and methods of computing or assessing damages for the diversion of water."

At the November meeting a committee of five was appointed to compile information relating to awards that have been made in water-works valuation cases.

At the same session a committee of five was appointed to prepare a standard specification for fire hydrants.

Three able committees have been appointed to consider these important subjects, and their findings, when presented, will prove of the greatest value.

Reports of the Secretary, Treasurer, Editor, and Auditing Com-

mittee will show in detail the standing of the Association as compared with that of a year ago.

We appreciate fully the good work of these officers, not forgetting the painstaking service of the Assistant Secretary.

I thank you for your support and consideration the past year, and let us bear in mind that the New England Water Works Association can move onward and upward only by the hearty coöperation of every member.

Report of Secretary.

Mr. President and Members of the New England Water Works Association, — I have the honor to submit the following report of membership, receipts and disbursements of the New England Water Works Association for the year ending December 31, 1907:

Membership.

The total membership of the Association of all grades Dec. 31, 1906, was .	684
,, ,, ,, ,, ,, ,, ,, ,, ,, ,, ,, 1907, ,, .	702
A net increase during the year of	18

The increase being in the grade of member, the list of honorary members remaining the same as last year, and the changes in the associate grade resulting in the present number of associates being the same as on December 31, 1906.

The present membership is divided among the different grades as follows:

Members	636
Honorary members	15
Associates	51
A total of	702

The detail of changes in membership is as follows:

Membership.

The total membership of the Association January 1, 1907, was	618
The present membership is	636
A net increase during the year of	18

members.

January 1, 1907.	Total members		618	
	Withdrawals:			
	Resigned	13		
	Died	6		
	Dropped	32	51	567

	Initiations:				
	January	4			
	February	5			
	March	10			
	September	19			
	November	5			
	December	4	47		
	Seven members elected in 1906 but qualified in 1907		7	54	
	Reinstated:				
	Members dropped in 1906		6		
	Members dropped in 1907		9	15	636

HONORARY MEMBERS.

January 1, 1907.	Honorary members		15		
January 1, 1908.	Honorary members				15

ASSOCIATES.

January 1, 1907.	Total associates			51	
	Withdrawals:				
	Resigned		2		
	Died		1	3	
				48	
	Initiations:				
	September		2		
	December		1	3	51
January 1, 1908.	Total membership				702

Summary of Receipts and Disbursements of the New England Water Works Association for the Year 1907.

RECEIPTS.

Initiation Fees			$256.00
Annual Dues:			
Members	$1 881.00		
Associates	750.00	$2 631.00	
Fractional dues:			
Members	$29.00		
Associates	15.00	44.00	
Past dues		29.35	
Total dues			2 704.35

Advertisements	$1 728.75
Subscriptions	167.75
JOURNALS sold	256.17
Sundries	42.30
Excess of receipts over expenditures June 26, 1907 (June Excursion)	23.78
Total receipts	$5 179.10

DISBURSEMENTS.

JOURNAL	$1 137.47
Assistant Secretary	600.00
Stationery and printing	400.49
Rent	400.00
Advertising Agent	306.00
Editor	300.00
Secretary	200.00
Stenographer	195.25
Incidental expenses	184.20
Membership list	150.50
Reprints	101.50
Music	80.00
Stereopticon	70.40
Treasurer	50.00
Badges	45.50
Insurance	15.00
Library	5.50
Total disbursements	$4 241.81*

Receipts in excess of expenditures	$937.29
At present there is due the Association:	
For advertisements	$280.00
For initation fee and dues	14.00
For JOURNALS	5.00
For subscriptions	3.00
For Standard Specifications	.80
Total	$302.80

I know of no outstanding bills against the Association except those for the December issue of the JOURNAL not yet received.

Respectfully submitted,

WILLARD KENT, *Secretary.*

On motion duly seconded the report of the Secretary was accepted and placed on file.

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* Note that this differs slightly from the Treasurer's statement since it includes two small bills which have been lost in the mails and are not yet paid.

REPORT OF TREASURER.

LEWIS M. BANCROFT, TREASURER,

In account with the New England Water Works Association.

RECEIPTS.

1907.			
Jan. 5	Balance on hand		$3 410.53
Aug. 1	Dividends, Peoples Savings Bank, Worcester		62.98
Dec. 7	Dividends, Mechanics Savings Bank, Reading		49.75
Feb. 4	Rec'd of Willard Kent, Sec'y,	$1 427.90	
March 6	" " " "	692.95	
May 8	" " " "	656.45	
July 10	" " " "	651.20	
July 23	" " " "	160.28	
Oct. 23	" " " "	775.20	
Dec. 6	" " " "	404.15	
1908.			
Jan. 3	" " " "	410.97	
			5 179.10
			$8 702.36

EXPENDITURES.

Paid bills, as per itemized statement		$4 222.06

BALANCE ON HAND.

Deposit Peoples Savings Bank, Worcester	$1 600.00	
Deposit Mechanics Savings Bank, Reading	1 202.95	
Deposit First National Bank, Reading	1 273.20	
Deposit Liberty Trust Company, Boston	404.15	
		4 480.30
		$8 702.36

READING, MASS., January 6, 1908.

LEWIS M. BANCROFT, *Treasurer.*

DETAILED STATEMENT OF BILLS PAID.

1907.		
January 15	Emerson H. Packard, music, January 9	$10.00
	Hub Engraving Company, plates	7.61
19	L. M. Bancroft & Son, treasurer's bond	15.00
February 7	Miss J. M. Ham, salary for January	45.00
15	D. Gillies' Sons, printing	66.02
March 8	Arthur D. Marble, auditor	3.00
	Harvard Quartet, music, February 13, 1907	25.00
	Hub Engraving Company, plates	2.81
	Miss J. M. Ham, salary to March 1	55.00
	D. Gillies' Sons, circulars	4.50
14	B. D. B. Bourne, stereopticon	10.00
	Boston Society of Civil Engineers, rent to February 28	100.00
21	Daggett's Orchestra, music, March 13	15.00
	Thomas P. Taylor, stereopticon	10.00
	Miss J. M. Ham, salary to April 1	50.00
	Charles W. Sherman, salary to March 31	75.00
	Charles W. Sherman, postage and express	8.00
April 15	Samuel Usher, printing	8.00
	Hub Engraving Company, plates	16.78
	W. H. Hughes, binding JOURNAL and index	5.50
	Bacon & Burpee, reporting January, February, and March meetings	70.00
	Robert J. Thomas, advertising agent, to April 1	82.75
17	Samuel Usher, March JOURNAL and reprints	360.50
	Willard Kent, salary as Secretary to March 31	50.00
	Willard Kent, sundry expenses	52.30
May 2	Samuel Usher, printing advance proofs	7.50
	Miss J. M. Ham, salary to May 1	50.00
8	Miss J. M. Ham, sundry expenses	39.72
	W. N. Hughes, envelopes	48.60
June 5	Miss J. M. Ham, salary to June 1	50.00
	Samuel Usher, lists of members	150.50
	W. N. Hughes, envelopes	24.00
19	Hub Engraving Company, plates	9.90
	John C. Chase, floral wreath for funeral of V. C. Hastings	10.00
	Miss J. M. Ham, salary for June	50.00
	Charles W. Sherman, salary to July 1	75.00
	Charles W. Sherman, postage and express	6.50
July 26	Miss J. M. Ham, salary for July	50.00
	Miss J. M. Ham, sundry expenses	39.79
	Amount carried forward	$1,759.28

		Amount brought forward	$1,759.28
July	26	Boston Society of Civil Engineers, rent to May 31,	100.00
		Willard Kent, salary to July 1	50.00
		Willard Kent, telephones	18.70
August	9	Samuel Usher, circulars	2.00
		R. J. Thomas, advertising agent	77.25
	20	Samuel Usher, June JOURNAL	264.65
September	5	W. N. Hughes, envelopes and printing	62.00
		Miss J. M. Ham, salary for August	50.00
	26	Charles W. Sherman, salary to October 1	75.00
		Charles W. Sherman, postage and expenses	7.00
		Whitehead & Hoag Company, badges	45.50
		Thomas P. Taylor, stereopticon	30.40
		The American Society of Mechanical Engineers, electrotypes	48.50
		Mary A. Powell, reporting twenty-sixth annual convention	66.00
October	23	Miss J. M. Ham, salary for September	50.00
		Miss J. M. Ham, sundry expenses	70.45
		Boston Society of Civil Engineers, rent to August 31,	100.00
		Willard Kent, salary to October 1	50.00
		Willard Kent, sundry expenses	19.80
November	7	Miss J. M. Ham, salary for October	50.00
		Springfield Photo-Engraving Company, plates	19.32
		Hub Engraving Company, plates	6.77
	19	W. N. Hughes, printing	13.50
		Samuel Usher, advance copies	28.00
		Hub Engraving Company, plates	12.36
December	13	Miss J. M. Ham, salary for November	50.00
		R. J. Thomas, advertising agent	74.00
		William E. Whittaker, drafting	2.50
		Hub Engraving Company, plates	19.90
		Thomas P. Taylor, stereopticon	10.00
	20	Boston Society of Civil Engineers, rent to November 30	100.00
1908.			
January	3	R. J. Thomas, advertising agent	72.00
		Miss J. M. Ham, salary for December	50.00
		Miss J. M. Ham, sundry expenses	20.81
		Samuel Usher, September JOURNAL and reprints	427.64
		Hub Engraving Company, plates	4.23
		Charles W. Sherman, salary to December 31	75.00
		Charles W. Sherman, postage, etc.	8.00
		Willard Kent, salary to December 31	50.00
		Amount carried forward,	$4,040.56

	Amount brought forward	$4,040.56
January 3	Willard Kent, sundry expenses	47.25
	Lewis M. Bancroft, treasurer's salary to December 31	50.00
	Bacon & Burpee, reporting November and December meetings	59.25
	Thomas P. Taylor, stereopticon	10.00
	The Brunswick, music, December meeting	15.00
		$4 222.06

Report of the Editor.

Boston, January 8, 1908.

To the New England Water Works Association: — I present the following report for the Journal of the New England Water Works Association for the year 1907.

The accompanying tabulated statements show in detail the amount of material in the Journal; the receipts and expenditures on account of the Journal for the past year, including the cost of the December Journal and reprints, bills for which were received too late to pay in 1907, and which are, consequently, not included in the Secretary's and Treasurer's statements; and a comparison with the conditions of the seven preceding years.

Size of Volume. — The volume is somewhat larger than for the preceding year, and larger than any preceding annual volume, with one exception.

Illustrations. — The total cost of illustrations for the year has been $228.68, or 8.7 per cent. of the gross cost of the volume.

Reprints. — The usual fifty reprints of papers have been furnished to authors without charge. Some few reprints have also been furnished to members who have contributed discussions, themselves almost in the nature of papers. The net cost to the Association for reprints and advance copies has been $133 (assuming that the December reprints chargeable to members are promptly paid for), amounting to $7.40 for each of the eighteen papers published during the year.

Circulation. — The present circulation of the Journal is:

Members, all grades	702
Subscribers	59
Exchanges	24
Total	785

an increase of 18 over the preceding year.

Advertisements. — The December issue contained 28¼ pages of paid advertising, which, if maintained throughout the year, would mean an annual income

from this source of $1 940. A year ago the figures were 26.08 pages and $1 740, showing considerable increase during the year.

Pipe Specifications. — During the year the specifications for cast-iron pipe to the value of $30.70 have been sold. There has been no corresponding expense, so this represents a net gain. The net gain up to a year ago had been $109.05, so that the total net gain from this source to date is $139.75. There is still a fair stock of specifications on hand, probably about $25.00 worth if sold at retail.

The last two issues of the year have been very much delayed in their publication, and the December issue has gone to subscribers only this week, consequently bills for printing it and for reprints could not be paid in time to be included in the 1907 bills as listed by the Secretary and Treasurer. They have, however, been included in this report, and they amount to $565.20. I know of no other outstanding bills against the Association on account of the JOURNAL.

Respectfully submitted,

CHARLES W. SHERMAN, *Editor.*

TABLE No. 1.

Statement of Material in Volume XXI, Journal of the New England Water Works Association, 1907.

Number.	Date.	Pages of Papers.	Proceedings.	Total Text.	Index.	Advts.	Cover and Contents.	Inset Plates.	Total.	Cuts.
1	March	73	35	108	–	31	4	2	145	5
2	June	73	9	82	–	32	4	2	120	16
3	September	117	17	134	–	31	4	3	172	16
4	December	166	10	176	8	31	4	13	232	60
	Total	429	71	500	8	125	16	20	669	97

TABLE No. 2.

Receipts and Expenditures on Account of Volume XXI, Journal of the New England Water Works Association, 1907.

Receipts.		Expenditures.	
From advertisements . .	$1 728.75	For printing Journal .	$1 508.99*
From sale of Journals .	256.17	For preparing illustrations	150.68
From sale of reprints . .	7.60	For editor's salary . .	300.00
Subscriptions	167.75	For editor's incidentals,	38.00
	$2,160.27	For advertising agent's commissions	306.00
		For reporting	195.25†
Net cost of Journal . . .	483.15	For reprints and advance copies	144.50
	$2 643.42	Gross cost of Journal .	$2 643.42

* Including $522.20 for December Journal (not yet paid).
† Including $43.00 for December reprints (not yet paid).

TABLE No. 3.

Comparison between Volumes XIV to XXI, inclusive, Journal of the New England Water Works Association.

	Vol. XIV. 1899–1900.	4 Numbers of Vol. XV. 1900–1901.	Vol. XVI. 1902.	Vol. XVII. 1903.	Vol. XVIII. 1904.	Vol. XIX. 1905.	Vol. XX. 1906.	Vol. XXI. 1907.
Average edition (copies printed),	1 100	1 200	1 200	1 200	900	900	900	1 085
Average membership	583	586	571	587	596	625	665	693
Circulation at end of year . . .	640*	617*	648*	656*	667	705	767	785
Pages of text	345	363	403	430	491	587	495	500
Pages of text per 1 000 members,	600	618	707	733	824	939	745	722
Total pages, all kinds	485	536	584	619	794*	784	662	669
Total pages per 1 000 members .	832	913	1 020	1 051	1 332	1 254	995	964
Gross Cost:								
Total	$1 954.15	$2 194.26	$2 439.99	$2 706.05	$2 928.77	$3 266.65	$2 573.61	$2 643.42
Per page	4.03	4.10	4.18	4.38	3.69	4.17	3.88	3.95
Per member	3.35	3.75	4.27	4.61	4.91	5.23	3.87	3.82
Per member per 1 000 pages .	6.91	6.99	7.32	7.46	6.18	6.67	5.85	5.70
Per member per 1 000 pp. text .	9.71	10.13	10.60	10.72	10.00	8.91	7.81	7.62
Net Cost:								
Total	$347.55	$332.90	$622.89	$770.62	$648.11	$1 072.95	$387.96	$483.15
Per page	.72	.62	1.07	1.25	.82	1.37	.58	.72
Per member	.60	.57	1.09	1.31	1.09	1.72	.58	.70
Per member per 1 000 pages .	1.23	1.06	1.87	2.12	1.30	2.20	.88	1.04
Per member per 1 000 pp. text,	1.73	1.57	2.71	3.05	2.22	2.93	1.18	1.39

* Exclusive of three hundred sample copies.

On motion duly seconded the Editor's report was accepted as read and placed on file.

THE PRESIDENT. The next thing on the program is the report of the Finance Committee. My impression is that the chairman of that committee is ill, and I think Mr. Cassell is the ranking member.

MR. CASSELL. Mr. President, owing to the absence of the two senior members of the Finance Committee — I mean in point of service only — I find that I, the infant member of the committee, have been called upon to read the report of the Finance Committee.

REPORT OF FINANCE COMMITTEE.

BOSTON, MASS., January 6, 1908.

In compliance with Section 5 of Article 6 of the Constitution of the New England Water Works Association, the Finance Committee, with the exception of Mr. Arthur D. Marble, who could not attend on account of illness, met this day at the headquarters of the Association and attended to their duties in auditing the accounts of the Treasurer and Secretary.

We examined the Secretary's books, verified the accounts, and found the total receipts, $5 179.10, as stated, to be correct, which amount he has turned over to the Treasurer, as his vouchers testify.

We examined the Treasurer's accounts and found that his receipts from the Secretary agree with the amount as stated above. We also examined the record of his payments and find them correctly recorded and properly certified and vouched for.

The disbursements amount to $4 222.06.

We find the invested fund in two savings banks, with interest to date, namely, $62.98 and $49.75, amounts to $2 802.95, and cash on hand to be $1 677.35, all as stated in the Treasurer's report, making a total of $4 480.30 as a balance on hand for the beginning of the year.

Your committee desires to commend the work of the Treasurer, Secretary, and Assistant Secretary for the clear and concise manner in which the books and finances of the Association are kept, and to acknowledge the courtesies extended by them.

Respectfully submitted,

WILLIAM E. MAYBURY.
GEORGE CASSELL.

On motion duly seconded the report of the Finance Committee was accepted and placed on file.

The President. It seems proper at this time to take up the matter of the acceptance or rejection of the Treasurer's report, it having been passed on and certified as being correct.

On motion duly seconded the report of the Treasurer was accepted and placed on file.

Pipe Specifications.

The President. The chairman of the Committee on Standard Specifications for Cast-Iron Pipe is present and desires to make a few remarks.

Mr. Dexter Brackett. The committee has no formal report to make, but as I have had during the past year some correspondence with the chairman of a committee of the American Water Works Association having this question under consideration, I think it may interest the members of this Association to know what is being done in the matter of standard water-pipe specifications by the American Water Works Association, as it may affect the action of this Association.

At the annual convention of the American Water Works Association held at Toronto in June, 1907, a committee of that association reported a form of standard specifications for cast-iron water pipe which follows very closely the wording and the tables giving standard dimensions and weights that have been adopted by this Association. They have, however, suggested some changes, the principal one being a reduction in the number of standard classes; and they have added a further set of tables giving standard thicknesses and weights for heavier pipes. The standards of the New England Water Works Association have 10 classes adapted for heads from 50 feet to 500 feet inclusive, while they have presented 8 standards adapted for heads from 100 feet to 800 feet.

They have not as yet got their specification in a form which your committee is willing to recommend for your approval. The differences are slight, but some of the changes proposed are not, in our opinion, any advance over the specifications which we have adopted.

It will certainly be much better if a standard which will be used by the entire country can be agreed upon, and we hope that this

may be accomplished and that the matter may be brought to your attention later, but your committee does not believe in the adoption of another specification which would be but little, if any, better than the one which has been already used for several years. The fact that your Secretary has sold during the past year about three hundred copies of the standard specifications, in addition to what have been quite generally distributed throughout the country in past years, shows that it is being used.

The President. The next item on the program is the report of the tellers appointed to canvass ballots. We would like to hear from Mr. Arthur F. Ballou.

Election of Officers.

Mr. Ballou. Your tellers have carefully counted the ballots and examined them, and present the following results:

REPORT OF TELLERS OF ELECTION.

Whole number votes cast	213
Not properly endorsed	9
For President.	
Alfred E. Martin	199
For Vice-Presidents.	
M. N. Baker	200
George A. King	200
Michael F. Collins	200
George F. West	200
William F. Sullivan	199
Robert A. Cairns	201
For Secretary.	
Willard Kent	202
For Treasurer.	
Lewis M. Bancroft	200
For Editor.	
Charles W. Sherman	200
For Advertising Agent.	
Robert J. Thomas	201
For Additional Members of Executive Committee.	
George W. Batchelder	200
D. N. Tower	200
George A. Stacy	201
For Finance Committee.	
George Cassell	200
John C. Chase	200
William E. Maybury	201

ARTHUR F. BALLOU.
S. A. AGNEW.

The President. The result of this election seems to be practically unanimous. I think we would all like to hear something from our newly elected president, Mr. Martin, who has been a member of our Association for twenty-two years, and is known and respected by the whole Association. [Applause.]

Mr. Alfred E. Martin. *Gentlemen of the New England Water Works Association,* — I have no doubt Mr. Whitney is just as pleased to hear from me at this time as we were to hear from him a year ago.

I thank you sincerely from the bottom of my heart for giving me the privilege and honor of presiding over our Association, a privilege and honor which in the wildest flights of my imagination I never hoped would be mine. [Laughter.] It is true I have been a member twenty-two years; I was elected at the memorable meeting — I think it was memorable, at least judging by reports; I wasn't present at the time — when the two associations, the American and ours, met together in Boston in 1885.

I assure you, gentlemen, that I appreciate this honor, and that my appreciation is just as great as though I could express it in language that would be more pleasing to you and more satisfactory to me. But I am no orator, and consequently you will have to accept the simple statement of the fact itself. If there are any of you present who have ever seen me in similar positions, you may know that I am a better worker than I am talker. I therefore will not take up more of your time, which is too valuable to be wasted. I thank you, gentlemen, once more. [Applause.]

The President. We all know that Mr. Martin is a worker, and it seems to us that he is also a very fair talker.

The Secretary has a few applications for membership, which we will put in at this time.

The Secretary read the names of the following four applicants who, having been recommended by the Executive Committee, were elected to membership:

William Atkins McKenzie, Meriden, Conn, engineer connected with the Carnegie Lake, Princeton, N. J.; Milton W. Davenport, New Britain, Conn., chemist in charge of sewage filtration plant; Walter E. Spear, Babylon, N. Y., division engineer, Board of Water

Supply; George W. Cutting, Jr., Weston, Mass., in independent engineering practice.

Mr. Harry L. Thomas, assistant superintendent of water company, Hingham, Mass., read a paper entitled "Experience with a Producer Gas Plant." It was discussed by Messrs. E. H. Gowing, Crowthers, S. H. McKenzie, F. L. Fuller, A. O. Doane, I. T. Farnham, George Cassell, and F. A. Barbour.

Mr. F. F. Forbes, superintendent of water works, Brookline, Mass., read a paper entitled "One Year's Practical Everyday Experience with an Automobile for Business, by a Water-Works Man." It was discussed by Messrs. Dexter Brackett, W. F. Sullivan, Coulters, and J. H. Flynn.

Mr. Freeland Howe, Jr., read a paper entitled "Action of Water on Water Pipes." It was discussed by Messrs. B. B. Hodgman, E. D. Eldredge, A. O. Doane, G. E. Winslow, S. H. McKenzie, E. B. Phelps, and F. L. Fuller.

The meeting then adjourned.

February Meeting.

Hotel Brunswick, Boston, Mass.,
February 12, 1908.

A regular meeting of the Association was held at the Hotel Brunswick, Boston, Mass., on Wednesday, February 12, 1908, at 2 P.M. President Alfred E. Martin occupied the chair, and the following were present:

Members.

S. A. Agnew, J. M. Anderson, M. N. Baker, C. H. Baldwin, L. M. Bancroft, G. W. Batchelder, J. F. Bigelow, C. A. Bogardus, George Bowers, Dexter Brackett, E. C. Brooks, G. A. P. Bucknam, George Cassell, J. C. Chase, C. E. Childs, H. W. Clark, J. H. Child, R. C. P. Coggeshall, M. F. Collins, W. R. Conard, J. W. Crawford, F. W. Dean, A. O. Doane, John Doyle, E. D. Eldredge, J. N. Ferguson, W. E. Foss, S. DeM. Gage, F. J. Gifford, A. S. Glover, F. E. Hall, L. M. Hastings, T. G. Hazard, Jr., H. G. Holden, J. L. Howard, W. S. Johnson, E. W. Kent, Willard Kent, Patrick Kieran, G. A. King, L. P. Kinnicutt, Morris Knowles, N. A. McMillen, D. E. Makepeace, A. D. Marble, A. E. Martin, W. E. Maybury, F. E. Merrill, Leonard Metcalf, H. A. Miller, William Naylor, R. R. Newman, O. E. Parks, E. M. Peck, J. H. Perkins, W. H. Richards, A. L. Sawyer, E. M. Shedd, C. W. Sherman, G. H. Snell, G. A. Stacy, W. F. Sullivan, C. N. Taylor, H. L. Thomas, R. J. Thomas, W. H. Thomas, J. A. Tilden, D. N. Tower, W. H. Vaughn, R. S. Weston, J. C. Whitney, G. E. Wilde, C.-E. A. Winslow, and G. E. Winslow. — 74.

Associates.

The Anderson Coupling Company, by F. A. Leavitt; Harold L. Bond Company, by Harold L. Bond; Builders' Iron Foundry, by F. N. Connet; Eagle Oil and Supply Company, by John L. Hamilton; Hersey Manufacturing Company, by Albert S. Glover, J. A. Tilden, and W. A. Hersey; International Steam Pump Company, by Samuel Harrison; Ludlow Valve Manufacturing Company, by H. F. Gould; H. Mueller Manufacturing Company, by George A. Caldwell; National Meter Company, by C. H. Baldwin, J. G. Lufkin, and H. L. Weston; Neptune Meter Company, by H. H. Kinsey; Perrin, Seamans & Co., by Chas. E. Godfrey; Platt Iron Works Company, by F. H. Hayes; Rensselaer Manufacturing Company, by C. L. Brown; A. P. Smith Manufacturing Company, by Fred N. Whitcomb; Thomson Meter Company, by E. M. Shedd; Union Water Meter Company, by E. M. Barnard, F. E. Hall, and Charles F. Merrill. — 22.

GUESTS.

F. L. Weaver, Harry Girard, A. H. Weaver, Lowell, Mass.; Frank H. Gunther, Dracut, Mass.; Henry W. Littlefield, of Allen & Reed, Inc., Providence, R. I.; George F. Merrill, Supt., Greenfield, Mass.; Hon. S. O. Bigney, Attleboro, Mass.; A. Fleming, Wm. J. Carroll, Joseph H. White, J. Rodney Ball, Dr. J. T. Collins, Lawrence, Mass.; Charles H. Andrews, Marlboro, Mass.; Hon. G. Louis Richards, Mayor, Malden, Mass.; H. S. Richards, New London, Conn.; L. H. Cornfel, Boston; C. H. Cooley, Westfield, Mass.; Fred M. Hutchinson, Somerville, Mass.; George A. Carpenter, Pawtucket, R. I.; E. E. Pinkham and D. A. Sutherland, Lynn, Mass. — 21.

[Names counted twice — 5.]

The President called upon Mayor Richards, of Malden, who addressed the Association briefly.*

THE PRESIDENT. I now have the pleasure of presenting to you, gentlemen, the Hon. S. O. Bigney, of Attleboro, who, as our friend the Mayor has said, will now proceed to furnish the oratory. Colonel Bigney represents one of the largest manufacturing jewelry establishments in the country, and has had the privilege and honor of serving as a member of the Governor's Council.

COLONEL BIGNEY. *Mr. President and Gentlemen,* — I am glad to note to-day that you are all on the water wagon. The Mayor has told you just what I am going to say, how I am going to say it, etc.; and he has also told you how good looking you are. Well, I agree with him; as I look into your faces I can see that you are all very good-looking, and that is no bouquet at all. I understand, by the way, that you men seldom give up your business after you once get hold of it, but you stay and stay for all time, or as long as you live.

I know you have a lot of business to attend to this afternoon. But as I listened to the tunes which were played by the orchestra over there, a little while ago, I was reminded that this was the birthday of Abraham Lincoln, the greatest American citizen living or dead, without any question. All any one has to do is to read the life of Abraham Lincoln and he will agree with that statement. No man yet has ever done justice to the memory of that great American, nor can he.

It is hard for us to-day to appreciate this splendid heritage which has been passed down to us. We cannot begin to appre-

* A report of Mr Richards' remarks was sent to him for revision, and has not been returned to the Editor up to the time of going to press.

ciate it unless we go back and read afresh the history of that great man's life, and the history of the Civil War, and think of the suffering of those who made it possible for us to enjoy the splendid inheritance which is ours.

Gentlemen, I am pleased to be here to-day; I am glad to look into your faces. Two of my fellow-townsmen from Attleboro are here. We have been doing great work in our town in bettering and increasing the efficiency of our water works. Of course we have been criticised for spending too much money, but we had to do it in order to meet the demands of our community. I feel satisfied that my friends can take care of themselves anywhere, even at home when our next election comes on. I thank you very much, gentlemen, for your kind attention. [Applause.]

The President called upon Mr. Morris Knowles, chief engineer of the Bureau of Filtration, Pittsburg, Pa., to open the consideration of the subject especially assigned for the afternoon, which was, "Filter Operations, Investigations for Additional Supply, and Construction of New Filter at Lawrence, Mass." He was followed by Mr. Arthur D. Marble, city engineer, Lawrence, Mass., who gave a history of the agitation of the subject in Lawrence, finally culminating in the construction of the new filter; Stephen DeM. Gage, biologist, Massachusetts State Board of Health at the Lawrence Experiment Station, who illustrated by lantern slides the construction of the new filter and made some particular reference to the bacterial results obtained by filtration and the effect on the health of the community; Sanford E. Thompson, consulting engineer, who spoke particularly of the collapse of a portion of the roof of the new filter during process of construction; and M. F. Collins, superintendent of water works, Lawrence, who spoke of the matter of typhoid fever.

The general discussion which followed was participated in by Mr. M. N. Baker, Mr. Robert S. Weston, and Mr. Charles N. Taylor.

The Secretary read applications for membership from the following-named persons, all of which had been properly recommended and approved:

Active. — Charles W. Gilbert, Woburn, Mass., student of state and local management of public water supplies; Frank H. Gun-

ther, Dracut, Mass., superintendent, Dracut Water Works; Richard D. Chase, New Bedford, Mass., with National Board of Fire Underwriters; Robert Ridgway, Poughkeepsie, N. Y., Board of Water Supply, New York City.

Associate. — Allen & Reed, Inc., steam, gas, and water-works supplies, Providence, R. I.

The Secretary was instructed to cast the vote of the Association in favor of the applicants above named, and, he having done so, they were declared duly elected members of the Association.

The Secretary read a letter from Mr. S. E. Tinkham, Secretary of the Boston Society of Civil Engineers, inviting the members to attend a meeting of the Society on Wednesday, February 19, at which Mr. Allen Hazen would describe his trip to Australia "and show a large number of lantern slides of the Brisbane Water Works, the Sidney Water Works, the Melbourne Sewerage and Sewage disposal, and many views of public interest."

Mr. George Bowers called attention to the fact that there is now pending before the Massachusetts Legislature a bill appropriating $10 000 for the making of a geological map of the state. The United States government, if the bill is passed, will also make an appropriation for the work equal to the amount appropriated by the state. He spoke of the great importance that such a map would be to water-works interests, and asked the members to urge their representatives in the legislature to vote for the bill, which is Senate Bill No. 47.

Adjourned.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Mass., January 8, 1908.

Present: President John C. Whitney and members D. N. Tower, Robert J. Thomas, A. E. Martin, L. M. Bancroft, George W. Batchelder, George A. King, Charles W. Sherman, and Willard Kent.

Four applications were received and recommended for membership, viz.:

George W. Cutting, Jr., civil engineer, Waltham, Mass.; Milton W. Davenport, chemist in charge of sewerage filtration plant, New Britain, Conn.; William Atkins McKenzie, civil engineer, Meriden, Conn.; Walter E. Spear, Division Engineer, Board of Water Supply, Babylon, Long Island, N. Y.

The committee on investment of funds reported recommending the purchase of bonds of the Lake Shore & Michigan Southern Railway, and, on motion of Mr. Sherman, seconded by Mr. Martin, and amended by Mr. King, it was voted:

The Treasurer be, and hereby is, authorized to invest funds of the Association to an amount not exceeding two thousand dollars ($2 000) in bonds of the Lake Shore & Michigan Southern Railway.

On motion it was —

Voted: That certain persons suspended from membership in the Association for non-payment of dues, which have now been paid, be and hereby are reinstated.

No further business appearing, meeting dissolved.

Attest: Willard Kent, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Mass., February 12, 1908.

Present: President A. E. Martin and members M. F. Collins, Robert J. Thomas, William F. Sullivan, L. M. Bancroft, D. N. Tower, George A. King, Charles W. Sherman, M. N. Baker, George W. Batchelder, and Willard Kent.

Applications were received and recommended for membership from:

Charles Walter Gilbert, of Woburn, Mass.; Robert Ridgway, of Poughkeepsie, N. Y.; Frank M. Gunther, of Dracut, Mass.; Robert Davenport Chase, of Westfield; and from Allen & Reed, Inc., of Providence, R. I., for associate membership.

Voted: That the June meeting of the Association be held at Plymouth, Mass., and that the President, Secretary, Editor, George A. King, and D. N. Tower, be a committee with full power to make all necessary arrangements.

The subject of the place for holding the next Annual Convention was brought up and, after discussion, the members were unanimously of the opinion that, if suitable arrangements could be made, it should be held at St. John, N. B., and the President, Secretary, Editor, George W. Batchelder, and William F. Sullivan were made a committee to make necessary arrangements therefor.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

OBITUARY.

Charles Hermany, chief engineer and superintendent of the Louisville, Ky., Water Company, died at his home in Louisville, on January 18, 1908.

Mr. Hermany was born in Lehigh County, Pa., on October 9, 1830. In 1853 he entered the office of the city engineer of Cleveland, Ohio, and in 1857 he went to Louisville and became connected with the water company. In 1861 he became its chief engineer and superintendent and held the position continuously until his death.

It was under the direction of Mr. Hermany that the filtration experiments were made by Mr. George W. Fuller which mark the beginning of mechanical filtration as a scientific process.

Mr. Hermany was president of the American Society of Civil Engineers in 1904. He was elected an honorary member of the New England Water Works Association on September 14, 1904.

BOOK REVIEW.

Modern Baths and Bath Houses. By Wm. Paul Gerhard, C.E. New York: John Wiley & Sons. 1908. 311 pp., $5\frac{3}{4} \times 9\frac{1}{4}$ inches. Many illustrations. $3.00 net.

To the ordinary reader it would seem that this book must contain almost all that could be written on the subject of baths and bathing. Yet the bibliography composing one chapter of the book covers seven pages and indicates that the subject is by no means exhausted. The book describes not only water baths, but also air baths, mud baths, medicinal baths, etc. The illustrations show all kinds of apparatus, as well as plans and views of baths for various purposes, and sixteen pages are devoted to complete specifications for a municipal bath-house. There is a good index.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XXII. June, 1908. No. 2.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

THE MANAGEMENT OF THE TYPHOID FEVER EPIDEMIC AT WATERTOWN, N. Y., IN 1904.

BY GEORGE A. SOPER, PH.D., CONSULTING ENGINEER AND SANITARY EXPERT, NEW YORK CITY.

[*Read March 11, 1908.*]

Mr. President, Members of the Association, and Guests: Before taking up the subject of my paper, I hope the Association will allow me to express my thanks for its kind invitation to come here and tell about the Watertown epidemic. This epidemic may at first seem to be an old story. There is nothing new in the general idea of a typhoid epidemic caused by a public water supply derived from a badly polluted river, and if I had nothing more novel than merely that to relate I should not have come. But there were some features connected with the epidemic, and particularly with its sanitary management, which I believe will be new to you. On these questions particularly I shall welcome a free expression of your opinion.

There is no body before which an account of this kind could be presented to greater advantage, a statement which is warranted by the fact that the New England Water Works Association is composed of practical and scientific men, many of whom have had valuable experience with typhoid and keep themselves abreast of the best measures of avoiding it. It is generally recognized that New England is a source and center of inspiration in sanitary matters, and so far as the prevention of typhoid is concerned, this Association has done its full share to build up and maintain that good reputation.

The typhoid epidemic which is here described occurred in the first few months of 1904 at Watertown, N. Y. It was an uncommonly serious outbreak, numbering about one half as many cases as occurred in the epidemic at Ithaca the year before, and placed Watertown third among the cities of the United States which had typhoid death-rates in excess of 200 per 100 000 of population in the year 1904.

The typhoid history of Watertown for some years prior to this epidemic furnishes an example of the results which generally follow when a polluted river is used as a source of drinking water. The conditions of pollution were evident, but their significance was, apparently, not thoroughly appreciated until too late.

Perhaps the greatest interest which attaches to the epidemic lies in the energetic measures which were taken to stamp it out. If the city had seemed indifferent to the danger of typhoid, it certainly was anxious to make all possible amends when the inevitable catastrophe occurred.

As to the circumstances which led the city to continue for years to use the polluted river as a source of water supply, little has been said or written, so far as I am aware, and it is not my purpose to discuss this matter here. It is possible that indifference to the quality of the water was more apparent than real. The water works were in the hands of a municipal water board composed of citizens of the highest character and intelligence. They had sought and obtained expert sanitary advice on more than one occasion. There is reason to believe that the board was neither unmindful of the danger nor unwilling to take steps to remove it, but it appears that a decision as to the exact nature of the radical measures of protection needed could not, for some reason, be decided on.

The population of Watertown, according to an estimate made by the Census Bureau of the United States Department of Commerce and Labor, was 24 194 on January 1, 1904. The area of the city is somewhat over 3 000 acres; its assessed valuation of property exceeded $10 000 000. It is a manufacturing city, owing its prosperity largely to water-power developments on the Black River at this point. The location of Watertown with respect to the Black River is shown in Fig. 1.

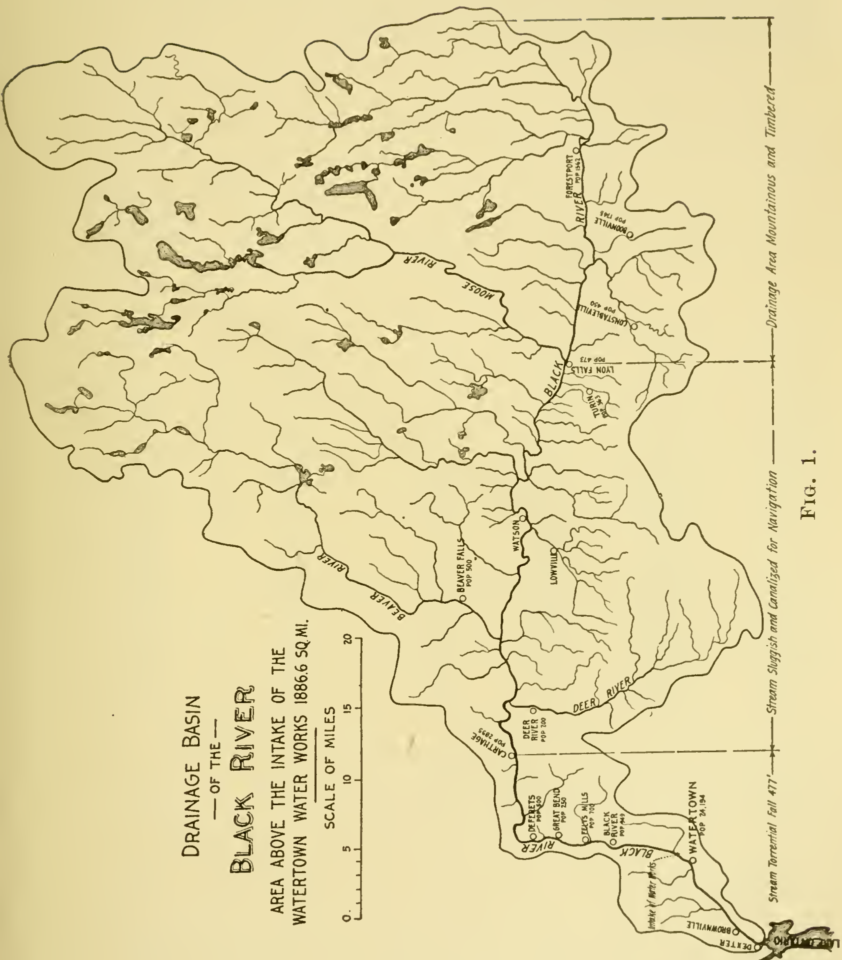

DRAINAGE BASIN
OF THE
BLACK RIVER
AREA ABOVE THE INTAKE OF THE
WATERTOWN WATER WORKS 1886.6 SQ. MI.
SCALE OF MILES
0. 5 10 15 20
Drainage Area Mountainous and Timbered
Stream Sluggish and Canalized for Navigation
Stream Torrential Fall 477'
MOOSE RIVER
BLACK RIVER
BEAVER RIVER
DEER RIVER
FORESTPORT
BOONVILLE
CONSTABLEVILLE
LYON FALLS
TURIN
WATSON
LOWVILLE
BEAVER FALLS
POP 500
CARTHAGE
DEER RIVER
DEFERIETS
GREAT BEND
POP 250
FELTS MILLS
BLACK RIVER
WATERTOWN
BROWNVILLE
DEXTER
LAKE ONTARIO

FIG. 1.

I.

PREVIOUS HISTORY OF TYPHOID AT WATERTOWN.

For many years typhoid fever had been unduly prevalent at Watertown, as is shown in Table I, in which the statistics for the city and state are given for twenty years.

TABLE I.

STATISTICS OF TYPHOID FEVER AT WATERTOWN, N. Y., FOR THE TWENTY YEARS 1885–1904.

Year.	Population.	Deaths from All Causes.	Deaths from Typhoid.	Per Cent. of Deaths from Typhoid to Deaths from All Causes.	Deaths from Typhoid per 100 000 Living.
1885	12 700	196	5	2.55	39
1886	13 100	229	5	2.18	38
1887	13 500	216	6	2.77	44
1888	13 900	296	8	2.70	58
1889	14 300	217	5	2.31	35
1890	14 700	234	7	2.99	47
1891	15 400	271	7	2.58	45
1892	16 100	376	12	3.19	74
1893	16 800	333	10	3.00	59
1894	17 500	323	15	4.61	85
1895	18 200	312	31	9.90	169
1896	18 900	331	11	3.32	58
1897	19 600	312	16	5.12	82
1898	20 300	340	22	6.47	108
1899	21 000	351	19	5.41	90
1900	21 000	397	24	6.04	110
1901	22 400	347	13	3.74	57
1902	23 200	317	16	5.04	69
1903	23 900	356	19	5.33	79
Average for Watertown for nineteen years,				4.17	71
Average for N. Y. state for same period,				1.3	25
For the epidemic year, 1904, at Watertown			47	12.81	194

NOTE. Since the epidemic the typhoid death-rate has been, per 100 000 of population, as follows: 1905, 24; 1906, 50; 1907, 37.

After 1894 there had been more typhoid than formerly. For the nine years preceding the epidemic of 1904 the average typhoid

death-rate had been 83 per 100 000 of population. The average for the whole state of New York for the twenty years prior to 1904 was 25, or less than one third that for Watertown. There had been, in the nine years previous to the epidemic, an average of 56 deaths from typhoid to 1 000 deaths from all causes in Watertown, while for the whole state, for the twenty-year period mentioned, the ratio had been 16 to 1 000. The records of the Board of Health show that typhoid existed at every season of the year, and that at various times it had been epidemic.

In 1895 two epidemics of typhoid occurred. One of these extended through April and May, and the other from August to December. The total number of deaths from typhoid fever in that year was more than twice that for the year preceding and three times that for the year which followed.

During the epidemic which occurred in the spring of 1895 suspicion centered upon the public water supply and the Board of Water Commissioners caused an investigation to be made to determine whether this was the source of the trouble. This investigation was made by the late Prof. Wyatt Johnston, the distinguished sanitarian, of McGill University, Montreal. The autumn epidemic was investigated by a committee of the Watertown Board of Health.

These two investigations, although made nearly ten years before the epidemic with which we are here chiefly concerned, throw such a strong light upon the conditions which led to the outbreak of 1904 that it seems desirable to pause for a moment to consider them.

The spring epidemic of 1895. The number of cases of typhoid which occurred in the spring epidemic of 1895 was, according to Professor Johnston's report to the Water Commissioners, 63. According to the records of the health office the number was 55. The Board of Health committee which investigated the epidemic which took place later in the year referred to the number in the spring outbreak as 80. The exact number cannot be ascertained, nor is it necessary that it should be. It is sufficient to note that an epidemic undoubtedly occurred in the spring of 1895.

Many circumstances led Dr. Johnston to suspect that the public water supply was the cause of the epidemic. Among fifty persons

suffering from typhoid fever, milk had been received from twenty-one peddlers, of whom only three had more than three cases on his route. The cases were distributed and not confined to any one section of the city. All of the patients had been regular drinkers of the public water supply. No one was ill who made it a regular practice to drink only boiled or filtered water. Most of the cases appeared after an unusual rise in the river; a freshet occurred between April 10 and 13, and most of the cases were recognized between April 20 and May 1.

The net result of Dr. Johnston's investigation was the opinion that the epidemic had come from the water supply. The supply had become infested with typhoid germs, in his judgment, from people in the many mills and other buildings which existed on the Black River above Watertown. He pointed out that unless these sources of pollution were remedied, typhoid fever would continue to be prevalent in Watertown and epidemics would occur from time to time. The danger to public health lay not in the volume of refuse which entered the stream, but in its quality; a large amount of factory drainage was far less liable to lead to disease than a small amount of sewage from water closets or the contents of privies. The existence of many possible points of pollution prevented the Black River from being regarded as a source of safe drinking water at Watertown unless the water was purified.

Dr. Johnston recommended the consideration of a plan for filtering the water, and advised that, pending such purification, a thorough inspection be made of the watershed, followed by the removal of all sources of direct pollution, especially privies, and the rigid suppression of nuisances in the neighborhood of the intake. Finally, he recommended that the intake be moved so as to be less liable to receive water from a polluted brook which entered the river nearby, and farther from the drainage of a neighboring cemetery.

Some of these recommendations were carried out, as we shall see later on. It was impossible, however, to remove the sources of pollution, "especially privies," which, as it will also appear, increased greatly in number as the Black River above Watertown was developed for mill purposes in succeeding years.

The second epidemic of 1895. According to the report of the

committee of the Board of Health which investigated the second epidemic of 1895 there were, in this latter outbreak, 180 persons attacked. Thirty-seven cases were accounted for on the theory that in September the milk supply of one of the numerous milk peddlers in Watertown became contaminated. The other cases were believed to have been caused by a contamination of the public water supply. The worst sources of pollution of the Black River were carefully described and mapped by Messrs. Boyer and Armstrong for this committee.

In concluding their report the committee recommended that the water supply be protected against the pollution which had, on two separate and recent occasions, caused much sickness and death in the city. The cases are reported to have occurred as follows: August, 56; September, 30; October, 63; November, 20; December, 12.

II.

THE PUBLIC WATER SUPPLY FROM THE BLACK RIVER.

The Water Works.

The drinking water supply of Watertown is taken from the Black River at a point about two miles about the city, as shown in Fig. 2. Here there is an arm of the river which has been dammed off from the main stream, making a stretch of quiet water about three quarters of a mile long, from two hundred to six hundred feet wide, and something less than eight feet deep. This is called the settling basin, and from its lower end the water for the city is drawn. The dam failed and was destroyed in December, 1901. It was rebuilt in 1902.

From a pumping station on the river bank the water was, at the time of the epidemic of 1904, pumped to a reservoir situated at an elevation of about 150 feet above the level of the stream. From here it flowed to the consumers by gravity. The reservoir capacity was about 5 000 000 gallons and the average daily consumption about 4 000 000 gallons. Theoretically, water taken in at the pumps should reach the majority of consumers within forty-eight hours.

No irregularity in the operation of the plant occurred after the dam forming the settling basin failed in 1901. A plant of rapid

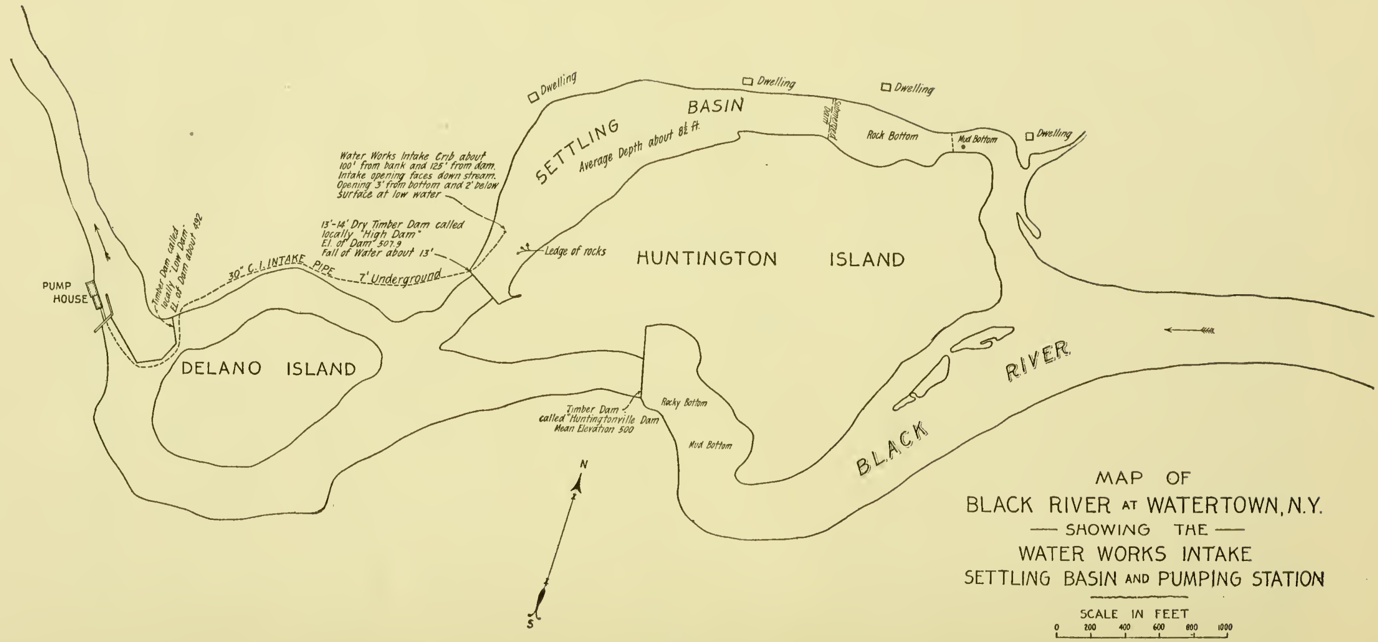

MAP OF
BLACK RIVER AT WATERTOWN, N.Y.
— SHOWING THE —
WATER WORKS INTAKE
SETTLING BASIN AND PUMPING STATION
SCALE IN FEET
0 200 400 600 800 1000
PUMP HOUSE
Timber Dam called locally "Low Dam" El. of Dam about 492
30" C. I. INTAKE PIPE
7' Underground
13'-14' Dry Timber Dam called locally "High Dam" El. of Dam 507.9 Fall of Water about 13'
Water Works Intake Crib about 100' from bank and 125' from dam. Intake opening faces down stream. Opening 3' from bottom and 2' below surface at low water
Ledge of rocks
SETTLING BASIN
Average Depth about 8½ ft.
Dwelling
Dwelling
Dwelling
Dwelling
Submerged Dam
Rock Bottom
Mud Bottom
HUNTINGTON ISLAND
DELANO ISLAND
Timber Dam called "Huntingtonville Dam" Mean Elevation 500
Rocky Bottom
Mud Bottom
BLACK RIVER
N
S

FIG. 2.

filters, designed by Allen Hazen, was begun in the autumn of 1903, and has been in service at the pumping station since the fall of 1904.

Quality of the Water.

The water of the Black River is naturally clear but colored with vegetable matter from the forests of the Adirondacks. It is soft and remarkably free from mineral matter except for a small amount due to mill drainage.

The quality of the water is likely to change rapidly with the changes which take place in the volume of the flow of the river. The flow varies from about 600 cubic feet per second to 18 000 cubic feet per second. The turbidity seldom rises above 200 parts per million as measured by the silica scale, and is usually very much lower than this figure. The water is improved somewhat in quality by passing through the sedimentation basin, but such figures as are at hand do not indicate that there is often a reduction exceeding about 50 per cent. in the numbers of bacteria. The chlorine in the river water is well above 0.3 parts per million, which is the normal in this vicinity. Presumptive tests for coli indicate fairly well the polluted condition of the river. Many analyses of the water have been made in connection with the operation of the filter plant, which was put in operation subsequent to the epidemic, but I am indebted to Mr. Francis F. Longley, who was for a time in charge of the operation of these works, for my information concerning this matter. Table II shows the results of some of Mr. Longley's chemical analyses.

TABLE II.

Results of Chemical Analyses of Black River Water.

(Parts per million.)

Date.	Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.	Chlorine.
October 4, 1904	0.186	0.030	0.001	0.15	0.90
November 2, ,,	0.112	0.012	0.001	0.05	1.05
November 28, ,,	0.074	0.002	0.002	0.10	1.20
December 18, ,,	0.092	0.020	0.002	0.05	0.90
January 9, 1905	0.116	0.014	0.003	0.10	1.00
February 10, ,,	0.078	0.006	0.001	0.25	1.25
February 28, ,,	0.072	0.006	0.001	0.15	1.15
March 20, ,,	0.216	0.128	0.003	0.20	1.10

So far as I am aware, no analyses of Black River water were made which adequately show the condition of the Watertown supply immediately before or during the epidemic. One sample was taken through the ice near the intake on February 15 and sent for analysis to Dr. R. M. Pearce, of the Bender Hygienic Laboratory at Albany. Dr. Pearce reported that this sample gave 14 200 bacteria per cubic centimeter on gelatine, and 280 on agar. The bacteria liquefied the gelatine with a "moderate putrefactive odor." Gas of the type characteristic of the colon bacillus was found.

The analysis shown in Table III, made by Mr. Longley during rises in the river one year later, perhaps give some idea of the conditions.

TABLE III.

RESULTS OF ANALYSES FOR BACILLUS COLI COMMUNIS IN WATER FROM THE INTAKE OF THE WATERTOWN WATER WORKS.

(By the word "gas" is meant 20 per cent. or more gas in dextrose broth.)

Month.	Average Discharge of River in Cu. Ft. per Second.	Results of Analyses.			
		Number Samples Examined.	Per Cent. Samples of 0.1 c.c. showing Gas.	Per Cent. Samples of 1.0 c.c. showing Gas.	Per Cent. Samples of 10 c.c. showing Gas.
October, 1904	4 700	11	9	91	100
November, ,,	1 920	18	33	100	100
December, ,,	1 650	20	35	95	100
January, 1905	2 640	17	47	100	100
February, ,,	2 380	15	20	93	100
March, ,,	4 010	20	50	90	100
April, ,,	11 350	15	27	80	100
May 1–10, ,,	6 905	6	0	66	100
		122	32	92	100

Physical characteristics of the Black River. The Black River rises in the heart of the Adirondacks, flows in an irregular, southwesterly direction, and empties into Lake Ontario. The distance from the mouth of the stream to the head of its principal tributary is 132 miles. Its total drainage area as given by the Report of the Board of Engineers on Deep Waterways, is 1903.2 square miles. The drainage area with some of the larger villages is shown in

FIG. 1. Intake of the Watertown Water Works, showing the Supply Main in the Foreground.

FIG. 2. Pump House of Watertown Water Works.

Fig. 1. The area above the intake of the water works is given by the same authority as 1 886.6 square miles.

The drainage area may be divided into two parts: a sparsely populated catchment area, which lies almost exclusively in the Adirondack Mountains, and a much more thickly populated, steep, narrow valley from Carthage, past Watertown to Lake Ontario. Parts of the upper portion of this catchment area have a rapid fall which sends down the waters from the rains and melting snows rapidly. In the distance of twenty miles from Carthage to Lake Ontario there is a fall of 477 feet. Through this valley the river flows in a turbulent and sometimes destructive manner. A large amount of the power due to the fall has been developed and is utilized by mills.

In 1902 there were on the drainage area of the Black River and its tributaries, according to the report of the New York State Water Storage Commission of 1903, forty-four dams, furnishing an aggregate of 76 000 horse-power to mills situated on the streams. The value of these mills was estimated at $12 302 100 and the annual value of their product at $15 101 440. There were 5 349 hands employed. Many of these mills were situated at Watertown, but, as will be seen presently, there were several villages along the Black River between Watertown and Carthage where mills, factories, and dwellings crowded the banks. There were a few mills beyond Carthage, at Lyon Falls, and elsewhere.

Sanitary condition of the Black River above Watertown. Through the coöperation of the Watertown Board of Health and the Water Commissioners of the city a careful sanitary inspection was made in 1895 of the shores of the Black River from Watertown to Carthage, a distance of seventeen miles. In this distance there were four villages which, with isolated country houses, had an aggregate population of over five thousand persons. Sketches of a few of these villages as they existed in 1895 are shown in Fig. 3. It appears, upon reliable testimony, that the population in this district had increased about fifty per cent. by 1904. An entirely new village, with a population of between four and five hundred persons, had grown up about a large paper mill at Deferiets, about ten miles above Watertown. To accommodate these people a sewerage system had been built to carry their sewage to the river.

In fact, sewage and other drainage entered from all the villages and mills without any restriction.

In the territory between Watertown and Carthage there were, in 1895, 165 buildings which drained into the stream. There were

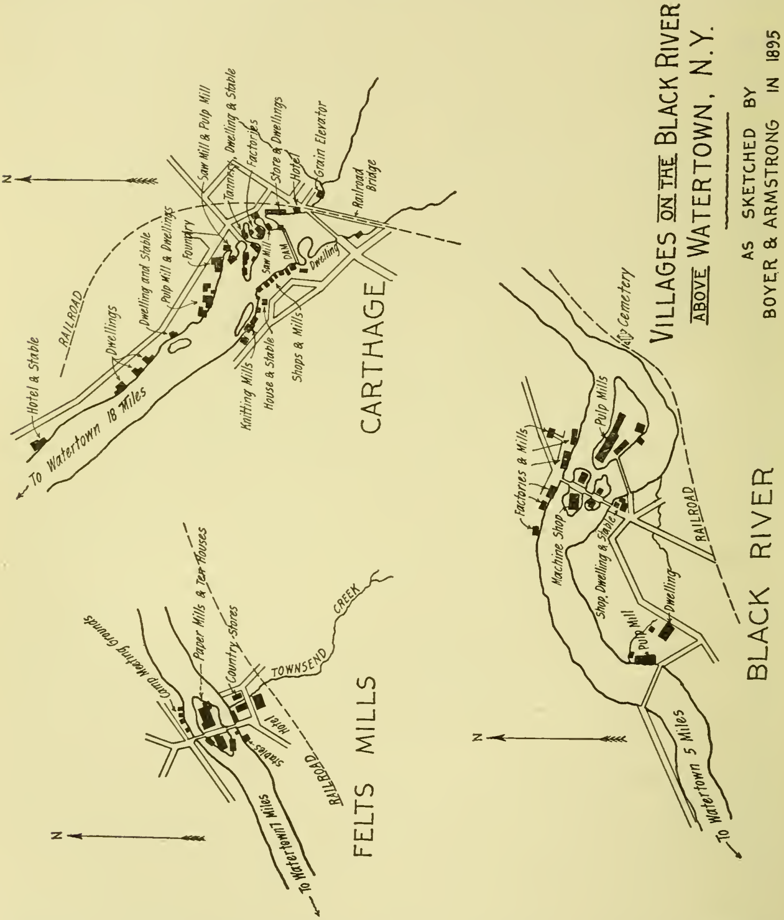


Fig. 3.

82 privies, 17 stables for horses, cattle, and hogs, 10 paper mills, 4 stores, 3 hotels, 2 bakeries. 15 shops of different kinds, and 5 other buildings used for different purposes. The 82 privies were used by about 740 persons and were located directly over the stream, or on its bank, and discharged their contents into the river.

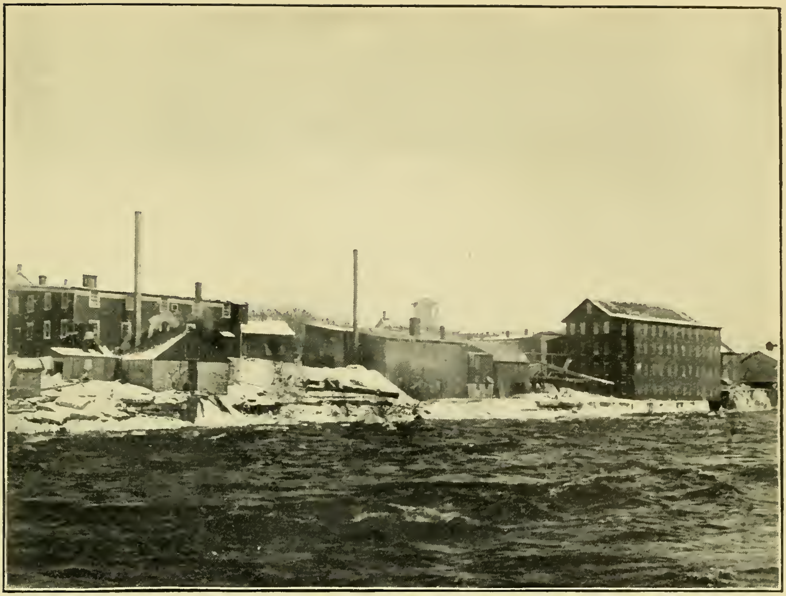


FIG. 1. Town of Black River, looking from the South Side of the Stream. This is five miles above the intake of the Watertown Water Works.

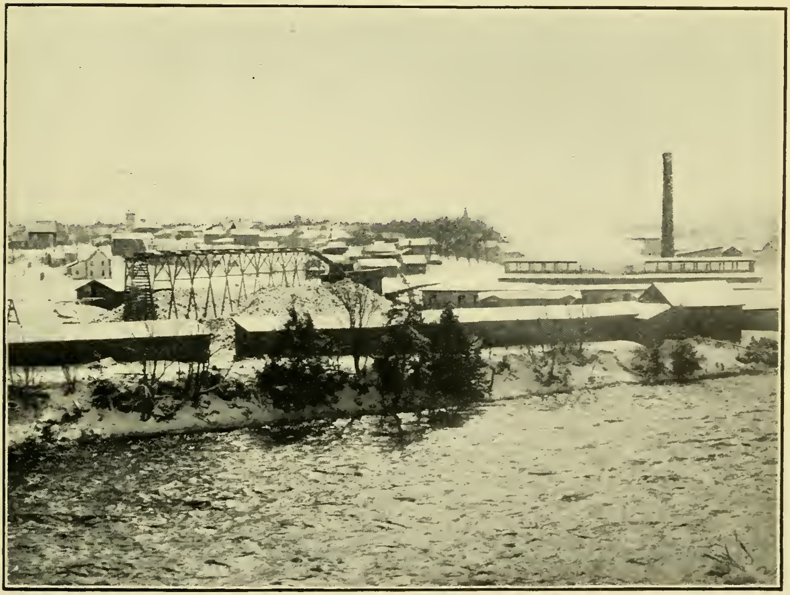


FIG. 2. Felts Mills, Seven Miles above the Intake of the Watertown Water Works.

The manure from the 17 stables was either thrown into the river or piled upon the bank, whence it drained into the stream. In addition to the 740 people whose excreta ordinarily passed directly into the river, about 6 000 to 7 000 people from different parts of the country attended annually a camp meeting held on the banks of the stream at Felt's Mills, seven miles above the intake of the Watertown water works. At this point four privies stood directly on the slope of the bank.

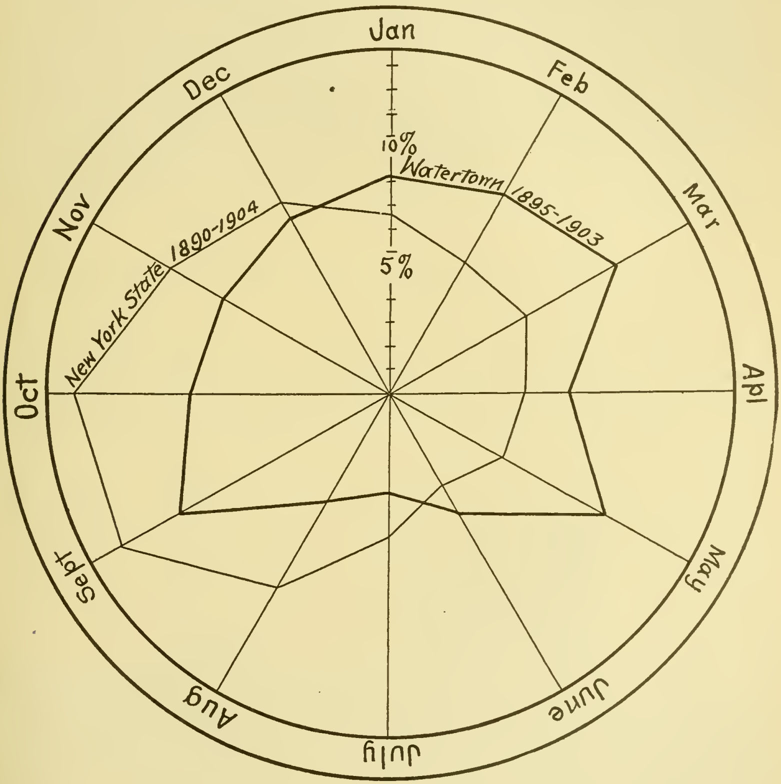


FIG. 4. Distribution of Typhoid Deaths through the Year in Watertown and New York State. The Distribution in the United States corresponds closely with that in New York State. The Peculiarities of the Watertown Curve suggest that the River Water has been a Leading Cause of Typhoid.

It seems unnecessary to point out the danger which these insanitary conditions represented. Aside from the probability that cases of typhoid fever existed every year among the persons who used the privies and sewers, not to mention persons who were chronic bacillus producers, the river was made the disposal place of refuse of every kind. Manure entered it from stables. It is well known that the manure of stables commonly contains human dejecta. It should also be remembered that when typhoid fever occurs in the country, it is usual to throw the stools and urine down the banks of the nearest stream to get rid of it. The Black River was, then, a very dangerous stream from which to take drinking water.

Ineffectiveness of State rules adopted for the protection of the Black River water supply. At the request of the Water Commissioners of Watertown, the State Board of Health, in 1896, formulated rules for the protection of the waters of the Black River from pollution above the intake of the water supply of the city of Watertown. These rules and regulations were made in virtue of Section 70 of Chapter 661 of the state laws of 1893, which empower the State Board of Health "to make rules and regulations for the protection from contamination of any or all public supplies of potable waters and their sources within the state" and "to impose penalties for the violation thereof and the non-compliance therewith."

As is the custom in New York state, the rules were published for six weeks in the principal papers of the district, in this case at Watertown, Carthage, and Lowville, and a certificate to this effect, together with a certified copy of the rules, having been filed in the office of the county clerk of Jefferson County, on April 30, 1896, the rules became law.

The Water Commissioners of Watertown thereafter had the legal right to insist that all dangerous pollution be kept out of the Black River above Watertown. But, as another provision of the public health law compelled the commissioners to bear the expense which this work incurred and also to make good any financial loss to mills and villages which might result, the cost of enforcing the regulations made protection of the water supply in this manner seem impracticable. The law was not enforced.

FIG. 1. Great Bend, from the North Side of the Stream. This is about eight miles above the intake of the Watertown Water Works.

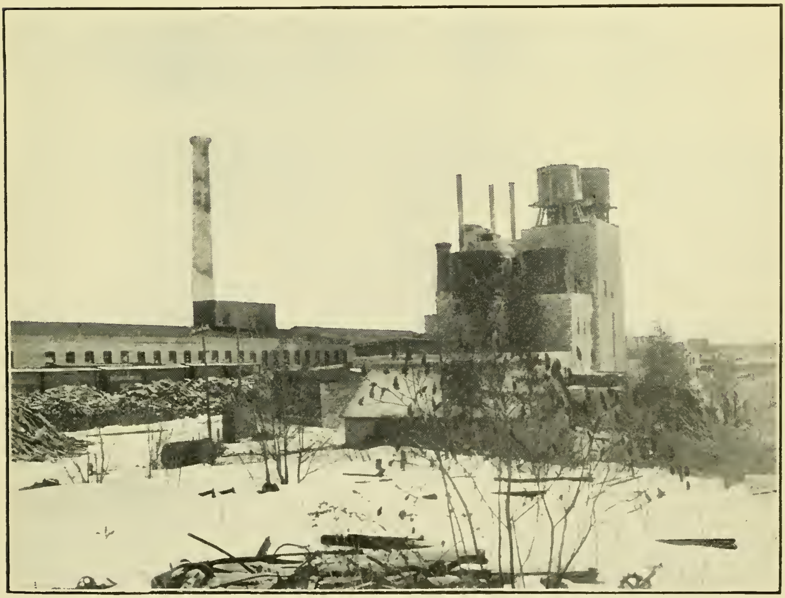


FIG. 2. Deferiets, Ten Miles above the Intake of the Watertown Water Works. A sewer empties into the Black River at this point.

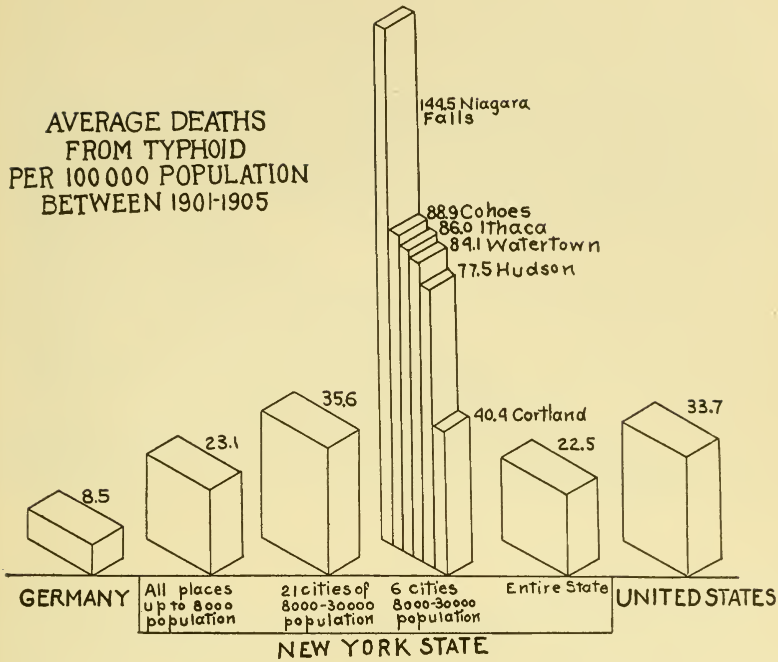


FIG. 5. Comparison between Typhoid Death-Rates for Germany, New York State, and United States. Also rates for six small cities in New York as compared with twenty-one other cities of the same in class New York State. The prevalence of typhoid at Watertown is thus made evident.

III.

THE EPIDEMIC OF 1904.

A study of the weather conditions preceding the epidemic of 1904 discloses some matters of particular interest.

The Weather.

To begin with, in the month of October, 1903, there were excessively heavy rains. These were followed by a long term of cold weather: the November of 1903 was decidedly colder than the average November. After the 18th of November the maximum daily temperature on the drainage area of the Black River was

generally below 32 degrees. The precipitation was light. The weather through most of the month of December was severely cold, the average temperature for the whole state being lower than for any similar period since the records of the United States Weather Bureau were begun. According to the Climate and Crop Service of the United States Weather Bureau, the ground was frozen and covered with snow throughout the month. In the drainage basin of the Black River an unusual amount of snow fell even for that remarkably cold and snowy section.

The intense cold which characterized the early part of December abated for nearly a week in the latter part of the month. Beginning with the 20th, the temperature rose every day above freezing at Lowville until the 26th. On the 20th there was a fall of .73 inch of rain at Lowville and .85 at Number Four. This was accompanied by a warm south wind. In the five days, December 20–24, 1.5 inches of rain, or its equivalent of snow, fell at Lowville, and in the three days, December 19–21, the fall at Number Four was 1.31. An excessively cold snap then followed and lasted throughout the month.

A large amount of water was washed from the snow-covered hillsides and banks of the streams by these rains and thaws. Sewers were flushed and ice in the vicinity of the sewer outlets was melted and carried off. According to records made by the Division of Hydrography of the United States Geological Survey, the discharge of the Black River at Felt's Mills, seven miles above Watertown, rose from about December 20. The rise was rapid and continuous until December 25, after which the flow diminished with slight remissions until January 9, 1904.

The source of the infectious matter. About a month after the outbreak of the epidemic, there were sent out a number of inspectors to determine, if possible, whether any cases of fever had occurred which could have led to the contamination of the water supply with typhoid germs. The search extended along the banks of the Black River as far as Carthage. One of the inspectors, Mr. W. E. Fuller, in a communication to *Engineering News*, March 3, 1904, page 205, has recorded what was found up to the latter part of February, 1904.

Going up stream from Watertown, the nearest cases of typhoid

FIG. 1. Carthage, from the West Side of the River.

FIG. 2. West Carthage, from Carthage. A sewer discharges under the further end of the bridge. This is eighteen miles above the intake of the Watertown Water Works.

were found at Black River, about 4½ miles above the intake of the water works. Five cases existed there: the first started during the latter part of December and the other four began in the first half of January, 1904.

No cases of typhoid were found in the next two villages, Great Bend and Felt's Mills.

At Deferiets, where there was a sewerage system emptying into the river about 10 miles above the intake of the Watertown water works, there was a small epidemic of typhoid at about this time. One case had occurred in September, 1903, a second in the first half of December, two more in the second half of December, and twelve in January and February. Deferiets has a population of about 500.

At the twin villages of Carthage and West Carthage, about seventeen miles above the water works, fifteen or sixteen cases of typhoid were said to have occurred from September to February. These villages are not provided with public sewers, although several private sewers empty into the river.

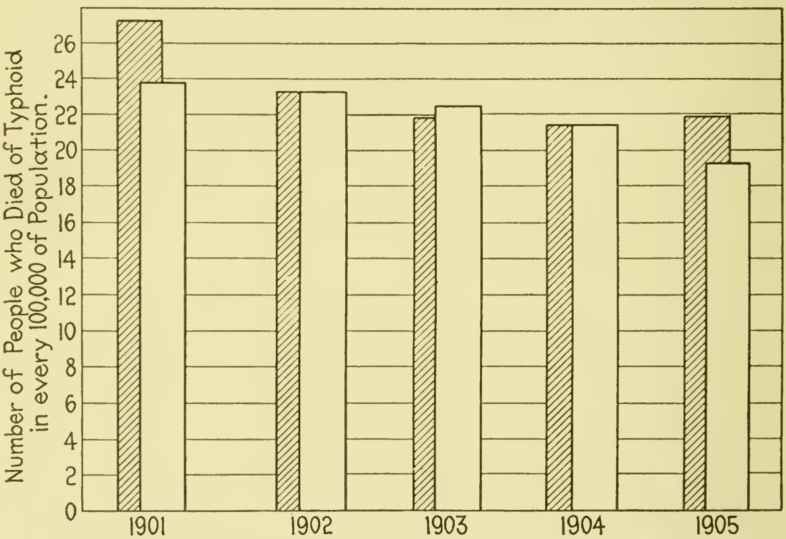
It thus appears that typhoid had existed at more than one of the villages between Watertown and Carthage before the outbreak at Watertown. How far typhoid had been prevalent in the thirty or forty settlements or villages on the drainage area above Carthage is not, and never will be, known.

Apparently there was within this watershed what has occurred in many other river valleys,— an epidemiological wave of typhoid. It is not difficult to understand how these waves occur. When typhoid is introduced at any point, the infectious matter gets into the water courses, which are, of course, the natural sewers of the country. As the sewers of one town become the water supplies of others, the disease is transmitted by the water down the valley in the direction of the flow of the stream. To some extent there is also an upward, downward, and lateral transmission of the disease, due to movements of the population and the transportation of milk from one village to another.

With a whole valley infected with typhoid, as was the valley of the Black River at the time of the Watertown epidemic, it is plain that the lower parts of the river are likely to become very heavily contaminated with typhoid germs and, owing to the numerous

points of pollution, may remain so for a long time. We have under these circumstances not an example of a sudden, intense, and brief contamination such as produce the most sensational explosions of typhoid, but a more continuously operating cause and a corresponding continuous effect. Instances of epidemics of this type have frequently been afforded by cities which draw their water supplies from large rivers. The statistics of the Watertown epidemic, although admittedly imperfect, seem to indicate that the public water supply of the city may have been contaminated in this manner.

Judging from the fact that many cases of typhoid occurred at Black River and Deferiets at about the time that the epidemic began at Watertown, it is barely possible that there was one large common source of germs which supplied all these places. In other



Among every 100,000 Inhabitants in New York State there Died

of Typhoid Fever in the Years:	1901	1902	1903	1904	1905
In Cities of over 8,000 Population ▭	23.8	23.2	22.3	21.3	19.1
" Places " less than 8,000 Population ▨	27.2	23.2	21.8	21.3	21.8

FIG. 6. Comparison between Rural and Urban Typhoid Death-Rates in New York State for Five Years, showing that in the year of the Watertown epidemic, typhoid was not unusually prevalent in city or country districts.

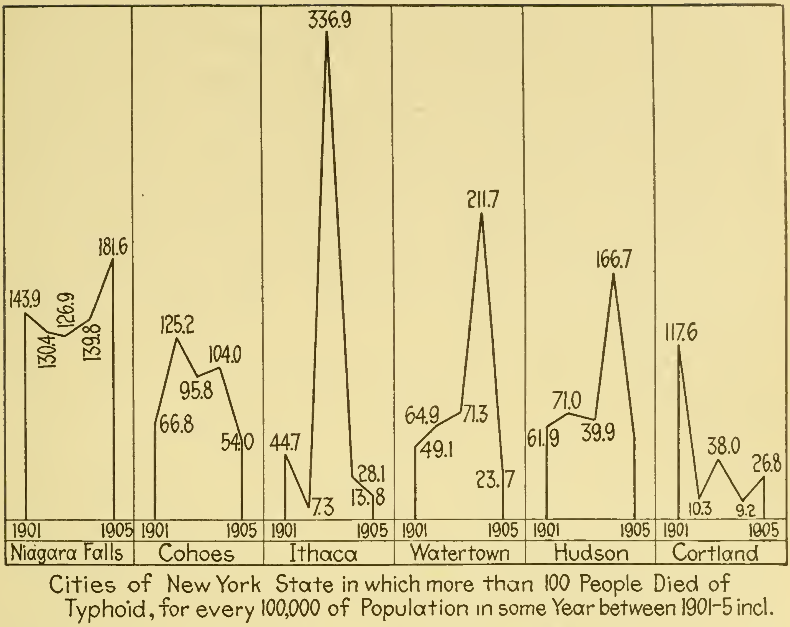


FIG. 7. Comparison between the Records of the Six Cities in New York State which had the Greatest Number of Deaths from Typhoid between the Years 1901 and 1906. According to the average rate, Watertown occupied fourth place; according to the rate for each year, Watertown was second.

words, it may be that the infectious matter which caused the Watertown epidemic originated above both Deferiets and Black River.

On the other hand, the germs which produced the Watertown outbreak may have come exclusively from some nearby point, such as Deferiets.

Setting aside this interesting but uncertain element as to the exact origin of the germs, the fact is clear that the epidemic at Watertown came from the public water supply.

The outbreak and course of the epidemic of 1904. According to the testimony of physicians, there had been an unusual amount of diarrheal disease in Watertown during the fall and early winter of 1903–4. During November and December typhoid fever had been much less prevalent than usual at this season of year. From

the reports of physicians made to Dr. E. S. Willard, health officer of the Board of Health of Watertown, it appears that the number of cases of typhoid for November was 7. In December the number reported was 15. On January 1, 8 cases were reported, and on the 2d, 13. In the following few days the number of new cases reported each day varied from 1 to 13. On January 15, 23 cases were reported. The newspapers now announced an unusual prevalence of typhoid, and, suspecting that the public water supply was to blame, the people were advised by the mayor to boil the water which they used for drinking purposes. The cases were widely scattered through the city.

The daily incidence of cases during the first few weeks is not clearly known, nor in fact are the dates of onset of the cases accurately established for any part of the outbreak. It was not customary for physicians to report their cases of typhoid with regularity before the epidemic and they did not do so afterward.

To a sanitarian unfamiliar with the peculiar conditions which occur in typhoid epidemics the failure of physicians to report their cases seems inexplicable if not inexcusable. The fact is, however, that physicians are extremely busy at such times in attending to the pressing needs of the sick, and are sometimes called upon to spend so much time in ministering to their patients that they feel unable to allow themselves proper time for sleep or meals. Often several visits are necessary before the nature of the sickness can be discovered. When a patient is at last found to be suffering from typhoid the date of onset may be forgotten. The full name and exact address of each patient is rarely known to an attending physician. To expect that every case of typhoid will be promptly and satisfactorily reported, therefore, is unreasonable, however desirable such reports may be from the public health standpoint. For a board of health to get even fairly satisfactory returns generally requires much telephoning, interviewing, and circularizing and sometimes a house-to-house canvass.

After the board of health work became systematized, each case reported was tabulated on two sets of cards. One of these sets was then arranged alphabetically according to the names of the patients and one set according to the street addresses. The sanitary circumstances surrounding each case were carefully inves-

tigated by the Board of Health and records kept of the principal points of information ascertained in connection with it. Many errors in the returns were corrected in this way. The genuine cases of typhoid were finally spotted on a large wall map and placed on a chart. In the stress of the hour some cases were probably overlooked by the physicians and the exact dates of others accidentally misstated. Some cases were reported several times and the addresses were frequently wrong. Some cases of disease other than typhoid were reported as typhoid. A curve plotted from the corrected returns in the possession of the Board of Health shows, as such curves always do, large numbers on some days and almost none on days immediately preceding and succeeding these. It is practically certain that people do not fall sick during typhoid epidemics in this extremely irregular way.

In the hope of eliminating some of the errors in the records, I have taken as an approximation to the probable number of cases each day an average of the number of cases for three days — the day before, the day itself, and the day after the date on which the number of cases is desired. The corrected returns and these averages with averages for each five days are given in Table IV. From these data I have plotted curves to give some idea of the progress of the epidemic. (See Fig. 8.)

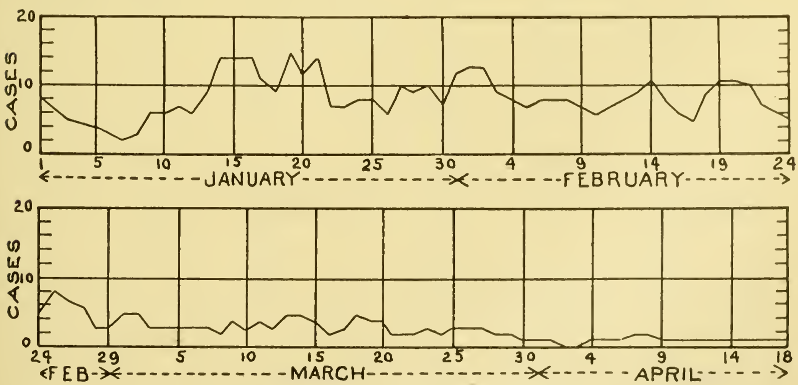


FIG. 8. Progress of the Epidemic of 1904. The Board of Health campaign was started about February 22. The upper curve represents the course of the epidemic before, and lower curve its course after, the repressive measures were put in force.

TABLE IV.

Cases of Typhoid Fever at Watertown, N. Y., from January 1, 1904, to April 18, 1904.

Date.		From Corrected Reports of Physicians.	Cases Averaged for Three Days.	Date.		From Corrected Reports of Physicians.	Cases Averaged for Three Days.
1904				1904			
January	1	8	10	January	31	6	12
,,	2	13	7	February	1	22	13
,,	3	0	5	,,	2	10	13
,,	4	1	1	,,	3	8	9
,,	5	2	2	,,	4	8	8
Total		24	25	Total		54	55
January	6	3	3	February	5	9	7
,,	7	3	2	,,	6	4	8
,,	8	1	3	,,	7	12	8
,,	9	4	6	,,	8	7	8
,,	10	13	6	,,	9	5	7
Total		24	20	Total		37	38
January	11	1	7	February	10	8	6
,,	12	7	6	,,	11	5	7
,,	13	10	9	,,	12	9	8
,,	14	9	14	,,	13	9	9
,,	15	23	14	,,	14	10	11
Total		50	50	Total		41	41
January	16	9	14	February	15	13	8
,,	17	10	11	,,	16	1	6
,,	18	14	9	,,	17	5	5
,,	19	4	15	,,	18	9	9
,,	20	26	12	,,	19	12	11
Total		63	61	Total		40	39
January	21	7	14	February	20	13	11
,,	22	8	7	,,	21	7	10
,,	23	5	7	,,	22	10	7
,,	24	8	8	,,	23	3	6
,,	25	11	8	,,	24	6	5
Total		39	44	Total		39	39
January	26	6	6	February	25	6	8
,,	27	8	10	,,	26	12	7
,,	28	15	9	,,	27	3	6
,,	29	5	10	,,	28	3	3
,,	30	10	7	,,	29	3	3
Total		44	42	Total		27	27

TABLE IV.—*Continued.*

Date.		From Corrected Reports of Physicians.	Cases Averaged for Three Days.	Date.		From Corrected Reports of Physicians.	Cases Averaged for Three Days.
1904				1904			
March	1	8	5	March	26	5	3
,,	2	5	5	,,	27	2	3
,,	3	2	3	,,	28	3	2
,,	4	2	3	,,	29	1	2
,,	5	4	3	,,	30	1	1
Total		21	19	Total		12	11
March	6	4	3	March	31	2	1
,,	7	2	3	April	1	0	1
,,	8	3	2	,,	2	0	0
,,	9	2	4	,,	3	1	0
,,	10	6	3	,,	4	1	1
Total		17	15	Total		4	3
March	11	1	4	April	5	0	1
,,	12	4	3	,,	6	1	1
,,	13	3	5	,,	7	2	2
,,	14	8	5	,,	8	2	2
,,	15	3	4	,,	9	1	1
Total		19	21	Total		6	7
March	16	0	2	April	10	0	1
,,	17	3	3	,,	11	2	1
,,	18	4	5	,,	12	0	1
,,	19	7	4	,,	13	0	1
,,	20	2	4	,,	14	2	1
Total		16	18	Total		4	5
March	21	2	2	April	15	0	1
,,	22	2	2	,,	16	0	1
,,	23	3	3	,,	17	2	1
,,	24	3	2	,,	18	1	1
,,	25	1	3	Total		3	4
Total		11	12	Grand total,			595

There is little doubt that the epidemic broke out about January 1, although it was not investigated until over a month later. The daily increase in the number of cases was apparently rapid up to about January 20, when there was a slight decrease until the 25th,

followed by another increase which lasted until about Feburary 1. The daily number of cases then declined slowly and remained comparativelv constant between February 9 and 25. After this there was a considerable reduction. The epidemic may be considered to have ended April 18. It had run 110 days.

The total number of cases of which I have reliable record was 595. The number of deaths to May 1 was 44. The case fatality, based on these figures, was 7.4 per cent.

Subsequent to April 18, 102 cases were reported up to January 1, 1905. The number of deaths from typhoid, in addition to those already mentioned, was 3 up to January 1, 1905. Since 1904 the number of cases and deaths from typhoid reported at Watertown have been as follows: 1905, 108 cases, 6 deaths; 1906, 130 cases, 13 deaths; 1907, 103 cases, 10 deaths.

When the cases of typhoid were spotted on a map it was seen that the fever had visited every part of the city. (See Plate V.) The poorer sections suffered most, and the aristocratic parts least, a result which was largely accounted for by the fact that the poorer sections were the most crowded and there were consequently more people to be attacked in a poor section on a given area. In the best residential quarters, also, more personal care was exercised to avoid the fever. The drinking water of many of the people was boiled or carefully filtered. Institutions, such as children's homes, and the jail, had their full share of typhoid.

There were some parts of the city which suffered to a greater extent than could be fully explained on the score of crowding and lack of personal precautions, and it seemed reasonable to conclude that some peculiarity of the distribution system of the water supply carried to these sections exceptionally large doses of infectious matter, or that insanitary conditions about the houses increased the people's chances of infection. No extensive local foci such as germ-infested wells were found, such as I had discovered at Ithaca. The people, as a rule, were in much better financial circumstances and lived more comfortably and there was much less typhoid transmitted from person to person than I had seen in the epidemic at Butler. Nevertheless, the fever was undoubtedly transmitted to some extent from person to person in spite of the utmost efforts of the Board of Health. The greatest danger in

Dots show Location of Typhoid Cases; Crosses show Location of Erysipelas Cases.

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this regard probably occurred when a patient was nursed at home. Under these circumstances the person who acted as nurse sometimes did the cooking for the rest of the family and, for convenience and warmth, the patient was occasionally nursed in a room close to the kitchen. As far as practicable these dangers were reduced to a minimum by the operations of the Board of Health.

IV.

MEASURES TAKEN TO CHECK THE EPIDEMIC.

At a meeting of the local Board of Health, held on February 1, it was decided to make an official investigation into the cause of the outbreak. It was fully realized that a serious epidemic was at hand. The health officer had notified the State Department of Health of the prevalence of typhoid under date of January 30.

State Action. On February 8 the health officer was empowered "to employ a sanitary expert at once to investigate the situation and take such measures as may be reasonable and necessary to eliminate the epidemic." In response to the information furnished the State Department of Health on January 30, Prof. Olin H. Landreth, consulting engineer of the State Department of Health, made the city a visit on February 13.

Professor Landreth caused a canvass to be made to ascertain the number and distribution of the cases and the date of attack in each case. He also advised that postal cards be sent to every family in the city, cautioning the people to boil the water used for drinking, for washing vegetables which were to be eaten uncooked, and for washing dishes, etc. Professor Landreth's suspicion rested upon the public water supply as the cause of the outbreak and he appointed canvassers to visit the settlements and shores along the Black River to search for any cause of typhoid which might have led to the contamination of the public water supply. At the same time data were collected which put the milk supplies out of question as the cause of the epidemic.

On February 20 Professor Landreth again visited Watertown. On this occasion the investigation which he initiated on his former visit was supplemented. Various sanitary measures were recommended and much salutary advice was given on sanitary matters.

Steps were begun toward cleaning and disinfecting all premises on the Black River where typhoid fever cases were found to have existed.

Other short visits were subsequently made to Watertown by Professor Landreth in his official capacity. On these occasions the need of extending the inspection and disinfecting work on the Black River drainage area were urged. But the city was less interested in cleaning up the drainage area than in attending to sanitary work within its boundaries. Eventually, by mutual consent, the direction of the work on the drainage area was placed wholly in Professor Landreth's hands, the city of Watertown agreeing to coöperate with the State Department of Health to the extent of paying the cost of this work.

Unable to secure from the state an expert who could give his undivided time to the work of checking the epidemic, and believing that the situation required such attention, the Board of Health engaged me for this purpose.

Plan of the campaign carried on by the city. A sanitary campaign was planned with the double object of checking the epidemic and restoring public confidence. Much of the work was based on my experience in the typhoid epidemic at Ithaca, N. Y., where I acted as the official representative of the State Board of Health and initiated through the local Board of Health an active campaign against the fever. I had been called to the Ithaca work, apparently, because I had had some experience with typhoid when I was the sanitary engineer of the New York City Department of Health.

The measures for controlling the epidemic which were carried out at Watertown during my connection with the city were largely based on the results of Koch's now famous studies at Trier, and the opinion which had grown out of my experience, that typhoid is not only infectious, but contagious, and transmissible from person to person.

The immediate objects of the campaign were the prevention of infection through the river water and from cases of typhoid already in the city. It was accepted by me as abundantly proved that the water supply had given rise to the original cases.

I advised that every typhoid patient be sent to hospital or

strictly isolated at home. No patient should be discharged from medical care until bacteriological tests showed that his excretions were no longer dangerous. All mild and suspicious cases of fever should be treated like typhoid. Secondary sources of disease, such as contaminated wells and milk supplies, were to be guarded against. All infectious matter should be destroyed by disinfection at its source. It was not practicable to put all these measures into effect; at least, not at once; nor ever with that completeness which was desirable. They were, nevertheless, kept always in mind and give the key to the principal work which was done by the Board of Health during my connection with it.

The sanitary work of the inspectors acting under the direction of the State Department of Health on the drainage area of the Black River and the natural flow of the river during two months of time seemed to me to have been sufficient to have removed every source of danger from the public water supply which it was practicable to remove. Still, in order to obtain the greatest measure of safety procurable, various steps were taken to secure protection from the public water supply. The distributing mains were flushed from the hydrants, one section of the city being taken at a time, and the work done in a thorough manner. The people were urged to continue to boil that portion of the water which it was necessary to use for drinking, dish-washing, and other purposes which might, by any possibility, lead to infection. The builders of the filtration plant were requested to push the completion of their work so that the plant could be made available at the earliest date.

Spring water supply. A supply of drinking water from springs of proved purity in the outskirts of the city was established and the water peddled from house to house at the nominal cost of one cent per gallon to the consumers. The price received for this water did not quite cover the expense of supplying it, but the outlay was trifling compared to the benefits received. As I had found in the epidemic at Ithaca, the distribution of spring water was greatly valued by the people.

To bring the water from the springs and deliver it from house to house a number of tank wagons were built. The tanks were made of galvanized iron of cylindrical shape. The capacity of these

tanks varied from 100 gallons to about 400 gallons each. They were filled through an opening at the top which was large enough to admit apparatus for cleaning. Each tank was sterilized at least twice a week with steam from a large paper mill in the central part of the city. The quality of the water was determined by daily analyses made from samples taken from the delivery wagons. The water was drawn from the tanks by means of large faucets.

At one time ten wagons were required to supply the demand for water. To facilitate the sale of the water, tickets were sold in quantity; these were exchanged by the water peddlers for the number of gallons wanted at each house. The tickets were used but once. The wagons followed fixed routes laid out on maps. Most of the city was covered in this way three times a week.

Examination of wells. Lists were made of the wells situated on private premises and on business property and arrangements were made to examine these waters. This examination consisted of, first, an inspection to determine the kind and depth of the well, its location with reference to houses, stables, and privies; the nature of the soil, and other points which would aid in interpreting the data obtained from an analysis of the water. At a later date a representative of the Board of Health visited the well and collected a sample of the water in a sterilized bottle. This sample was generally analyzed within four hours. It was examined for chlorine, hardness, number of bacteria, and the presence of coli by the presumptive test. An opinion was drawn from the results of the analysis and the record of the inspection and this opinion was then communicated to the owner of the well by postal card. Some wells were examined several times. Most wells were of unsatisfactory quality. It was necessary in a few cases to condemn and order wells closed. This was always done after a full discussion of the circumstances before a formal meeting of the Board of Health, the well being provisionally closed from the time when its condition was first determined.

Hospital arrangements. Owing to the unusual number of patients requiring to be accommodated, and the limited amount of space available for them, the two regular city hospitals were, at the height of the epidemic, greatly overcrowded. The City Hospital with forty regular beds had sixty patients. A hospital

operated by an order of Sisters of Charity, with thirty-five beds under normal conditions, was caring for fifty patients. The insanitary conditions which generally obtain in overcrowded fever hospitals were unmistakably exhibited in both of these institutions. A succession of cases of a peculiarly malignant form of erysipelas, generally accompanying typhoid, occurred in the City Hospital and in the Sisters' Hospital. Neither hospital had proper means of isolating cases of contagious disease. It therefore became necessary for the Board of Health to make arrangements for the accommodation of erysipelas and typhoid cases elsewhere. This work was done with the utmost dispatch.

Through the cordial coöperation of the Department of Charities, the headquarters of the Department on Massey Avenue were vacated and quickly made available for the erysipelas patients.

In preparing this house for its new use, every movable article was first taken out. The floors were then cleaned and painted,

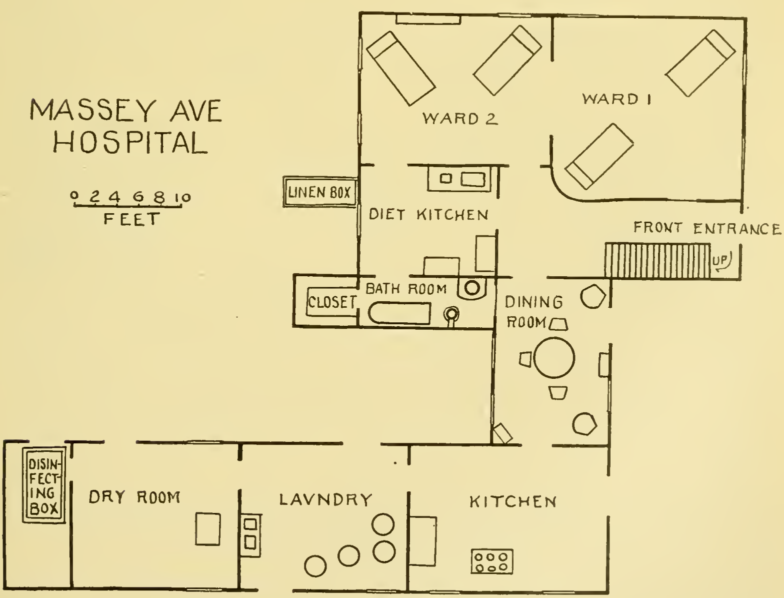

FIG. 9. Temporary Hospital on Massey Avenue opened for the Care of Erysipelas Patients, chiefly sent from the Overcrowded Permanent Hospitals of the City.

the plumbing overhauled, a disinfecting chamber large enough to contain a double mattress was constructed, a laundry was fitted out, and the house was furnished with high beds and all other appurtenances of a first-class temporary hospital. (See Fig. 9.)

In drafting the hospital regulations for this house, three general principles were kept prominently in mind: First, every part of the building was to be kept in a state of surgical cleanness. Second, no excretions, bedding, food, clothing, or other possible source or vehicle of infection was to leave the building, or the ward, if that was practicable, without disinfection. Third, every window and door was to be kept open as much as possible, and the patients, protected by screens, were to be given as much fresh air as they and their attending physicians would permit.

The results were entirely satisfactory. The disease did not spread to any of the attendants or nurses as had been the case before this temporary hospital was opened. Eleven severe cases of erysipelas were treated in this hospital. Seven were complicated with typhoid fever. The majority were in an advanced stage of the disease when admitted. One patient died. The rest recovered.

In order properly to care for the typhoid fever patients who could neither be accommodated at the permanent city hospitals nor isolated satisfactorily at their homes, a special typhoid hospital was opened. Much difficulty was experienced in finding a suitable building for this purpose. It was finally decided to use a new high school building which had just been completed at a cost of about $100 000, but not yet equipped with school furniture. Serious objection to this proposition was made by the Board of Education, but the health authorities decided that its conversion into a hospital was a necessary step and took temporary possession of the property.

The class rooms on the main floor of the school building were divided into male, female, and children's wards. A surgical ward was equipped and kept ready for emergency in case operations for perforation became necessary. Each patient had a minimum of 64 square feet of floor space and 770 cubic feet of air space. Separate rooms were reserved for patients who were very sick. Diet kitchens with gas stoves and instantaneous water heaters were established in the main hallways. Accommodations for the nurses

were provided on the second floor. A kitchen, a dining room, and a laundry were arranged in the cellar; later, the dining room and kitchen for the nurses and attendants were moved to the top floor. (See Fig. 10.)

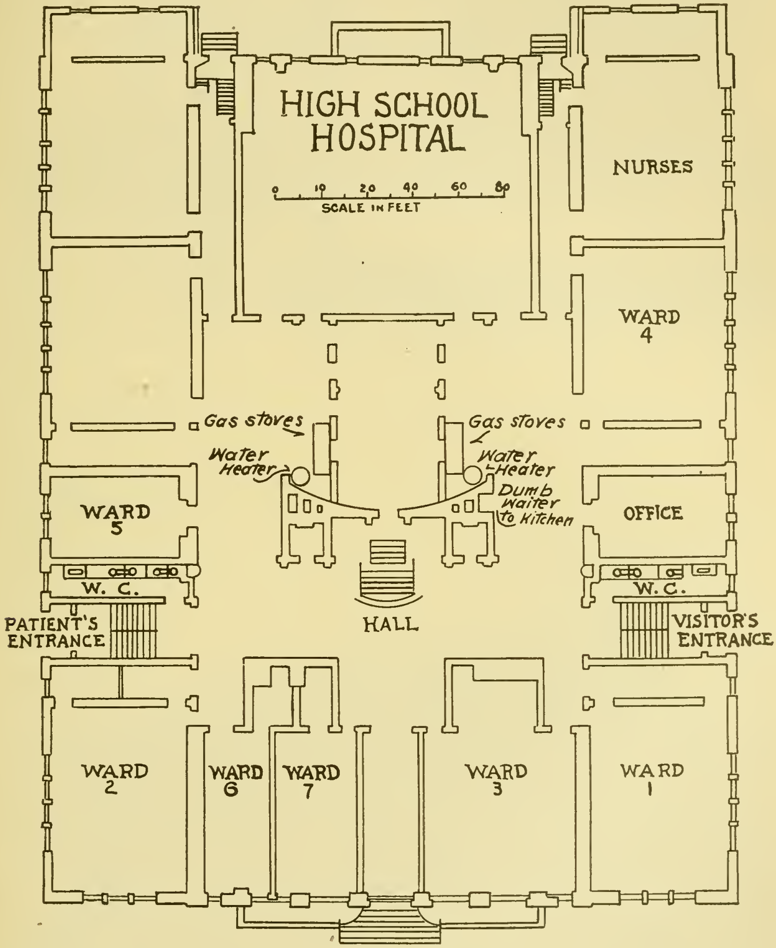

Fig. 10. The School Building which was taken by the Board of Health and turned into an Emergency Hospital for Typhoid Patients. About one hundred patients were treated. No case of typhoid occurred among the nurses, doctors, or attendants.

Rules and regulations for the management of this hospital were drafted on similar lines to those adopted for the erysipelas hospital, but they were less severe. Abundance of air in all parts of the building, thorough cleanliness in the wards, halls, closets, and nurses' dormitories, and prompt disinfection of the excretions and articles possibly contaminated with the excretions, and skillful nursing were the principles most insisted upon.

The disinfectants used were fresh milk of lime for the stools and urine, and 1 to 1 000 bichloride of mercury solution for cloths, hands, and floors. Sheets, pillow cases, and the garments of the patients, when removed, were placed in cloth bags at the bedsides and taken at once to the cellar where they were disinfected and washed. Sputum and cloths soiled with excreta, urine, or sputum were put into paper bags at the bedsides and removed in iron ash cans to a furnace in the building and burned. The cups, dishes, spoons, and other articles used in feeding the patients were kept separate for each case and regularly sterilized by boiling. The floors of all the wards were mopped with 1 to 1 000 bichloride each day. No sweeping was permitted in any part of the building. Care was taken to avoid the production of dust, by the use of damp cloths. No receptacles for milk or water were allowed to leave the building. The hospital was furnished with a fresh supply of spring water daily.

Dr. Philip C. Washburn, a graduate physician, was placed in charge of the hospital. Dr. Washburn slept in the building and was thus able to render prompt and valuable emergency aid on several occasions at the bedsides of the patients. Fortunately, no surgical operations were required. Besides Dr. Washburn, Drs. Spencer and Bibbins, prominent members of the medical profession in Watertown, kindly volunteered to serve as official medical consultants in case of need. The presence and advice of these gentlemen in connection with the medical care and nursing of the patients proved to be of great value.

None but picked graduate nurses was employed at either of the two hospitals conducted by the Board of Health. With a single exception they proved themselves capable, conscientious, and unfailing in the performance of their duties. The total number of nurses employed was 22, of which 17 were connected with the High School hospital and 5 with the erysipelas hospital.

FIG. 1. Massey Avenue Temporary Hospital, used for Erysipelas Patients. Strict isolation and disinfection were practiced. No one contracted erysipelas from these patients after they were brought here.

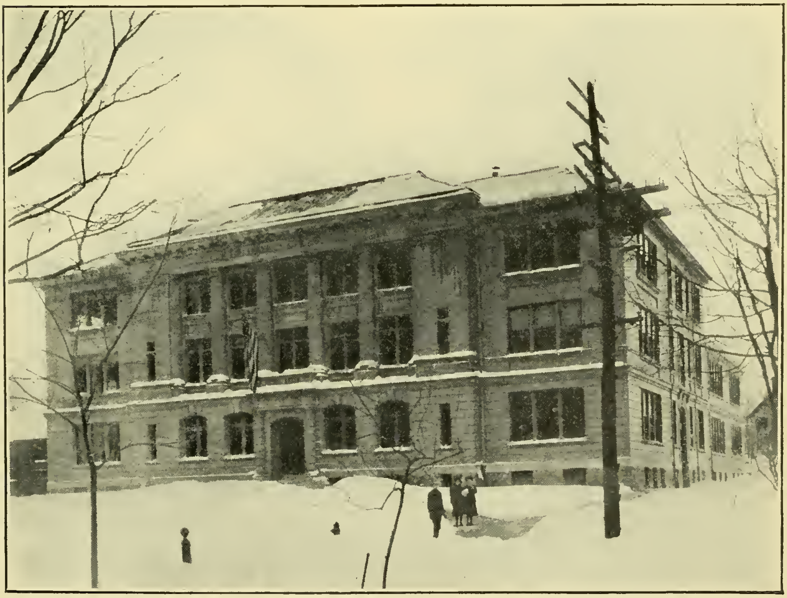

FIG. 2. New High School on Sterling Avenue, used as an Emergency Hospital for Typhoid Patients. About one hundred patients were treated here, mostly on the first floor.

The number of typhoid patients treated at the High School hospital was 97. There was but one death. None of the employees contracted the fever.

The expense of equipping and maintaining the hospitals was borne by the city. Each patient or his friends was expected to pay what he could afford for the nursing and care which the city provided, reckoned on a basis of $4.00 per week. Medical attendance was extra, and, except in indigent cases or emergencies, was provided by the patient or his family. Any physician in good standing was permitted to send and attend cases of typhoid at this hospital. For the removal of the patients from their homes, a specially constructed ambulance was provided without charge.

It is impossible to refrain from referring to the valuable help given by the ladies of Watertown in fitting out these two hospitals. Much help in the way of purchasing supplies, sewing, and aid of a kind that men cannot give was contributed by them with a promptness and generosity which added much to the success of the undertaking.

The bacteriological laboratory. A bacteriological laboratory was established for the analysis of water, milk, blood, urine, and other work in connection with the suppression of the epidemic. All the apparatus was of the best quality and purchased new. Dr. Herman Requi, of the University of Chicago, was placed in charge of the laboratory and was given enough help to enable him to turn out prompt and accurate reports. The work of this laboratory was done at the expense of the city and without charge to any individual.

Widal examinations to assist in the diagnosis of suspected cases of typhoid fever were given first place in the routine of the laboratory. No limit was placed upon the number of examinations which would be made for any physician or patient. If a specimen of blood reacted negatively, the physician who sent it was advised to furnish another specimen from the patient at a later date.

As I had found elsewhere, the only practicable way to obtain many specimens of blood for the Widal test was in the form of drops of blood dried on cards. Several races of typhoid and typhoid-like bacilli were kept in culture and were used when the

ordinary typhoid bacillus failed to agglutinate in proper dilution with the serum dissolved from the dried blood. Up to April 21, there had been examined 251 samples of water, 98 specimens of blood, and 95 specimens of urine.

Board of Health disinfectants. Disinfection was practiced in several ways. At the outset an effort was made to introduce uniform methods of disinfection in as many of the fever houses as possible. Because of the unreliability of the proprietary disinfectants sold in the shops, the Board of Health established a central disinfectant bureau and from this point distributed, without cost to the consumers, disinfectants throughout the city. Several wagons were employed to carry freshly slaked lime and concentrated bichloride of mercury to each house in which a case of typhoid fever was known to exist. Every fever house was thus visited twice a week, sometimes oftener. The disinfectants which were sent out on the wagons were known as "white fluid" and "blue fluid," and were of such concentration that, upon adding to either four times its volume of water, it would be of proper strength for use. The milk of lime, or white fluid, when ready for use, was composed of one part of freshly slaked lime to eight parts of water. The bichloride of mercury solution employed consisted of one part of bichloride of mercury to one thousand parts of water; this was made acid with hydrochloric acid and colored blue with common washing bluing. Directions for using both of these disinfectants were printed in large type on stout sheets of cardboard and left at each house where the disinfectants were employed.

Fumigation with formaldehyde was performed by the Board of Health at each house after a case of fever unless there was good reason to believe that this precaution was unnecessary. The method of generating the formaldehyde first used was that regularly employed by the Watertown Board of Health. It consisted in the use of a lamp with paraform pastils from which the gas was expelled. Later, because of the large number of houses which needed to be fumigated, a more rapid method was adopted. After the room had been closed as air tight as possible, and rugs, draperies, bedding, and other similar articles had been hung on chairs or suspended in the middle of the room, a large sheet was hung up. From a small watering pot there was then poured upon this sheet

a solution of formalin of 40 per cent. strength, in the proportion of at least 3 pints for every 1 000 cubic feet of air space, not allowing for the space taken up by the furniture and other articles in the room. After twenty-four hours all the windows were opened and the place thoroughly ventilated for at least two days. A careful scrubbing of the woodwork with soap and water and a brushing of the upholstery and drapery followed.

As a test of the efficiency of the fumigation, threads freshly impregnated with typhoid bacilli from twenty-four hour broth cultures were exposed in the room during the vaporization of the formaldehyde. After the disinfection the threads were immediately placed in sterile broth in the laboratory. If there was no growth this was taken to mean that the fumigation had probably been sufficient to destroy such bacilli of typhoid as may have been in the room as a result of its occupancy by the typhoid fever patient.

Other sanitary measures. The steps thus far described were the principal ones taken to prevent the spread of the fever, but they were not all. In many other ways the Board of Health endeavored to check the epidemic. The physicians were urged to report their cases accurately and promptly, and if they did not all comply, it was less the fault of the local board than to the neglect of this custom which commonly prevails in American cities.

Complaints of alleged nuisances were diligently investigated, and an effort made to have all houses and back yards put in order. The regulations of the Board of Health were revised, collated, and digested. The questions of garbage collection and disposition were studied, and the existing and other possible means of disposing of household wastes were inquired into.

Learning that smallpox existed in the vicinity of Watertown, an isolation hospital on the outskirts of the city was kept especially for the reception of patients suffering from this disease. Fortunately, it was not needed, but in anticipation of an emergency it was overhauled, cleaned, and put in readiness.

The sanitary awakening which resulted from the epidemic was the more remarkable from the fact that Watertown had been, in spite of its long and sinister typhoid history, a more than ordinarily well-regulated city.

Coöperation received in the sanitary campaign. As soon as the Board of Health began active work for the control of the epidemic, gratifying evidences of coöperation became apparent in many directions. The hospital authorities asked the board for help in difficulties connected with the overcrowded conditions of the hospitals, and offered such aid as they could give in other directions. Requests came from the press and the pulpit for interviews and addresses on sanitary topics. Organizations, corporations, and private citizens tendered their services and desired to be instructed in ways in which they might be of assistance in the general sanitary campaign. It was thus comparatively easy to carry to the people a knowledge of those principles of sanitation which were peculiarly applicable to the situation.

In endeavoring to give the instruction desired, particular emphasis was placed upon the value of simple but thorough methods of cleanliness and order, indoors and out. It was early pointed out that it was desirable that the storm doors and windows which had closed many houses from the outer air during the whole of the long, severe winter be removed as soon as possible. As the spring advanced, the people were advised to begin their annual house-cleaning early and make the work more than ordinarily thorough. Improved methods of collecting and disposing of the wastes so produced were undertaken by the city.

On the educational side, conferences were held with the physicians who practiced in Watertown and vicinity, and addresses were made before the local medical societies. The subjects dealt with on these occasions included the discussion of the nature and origin of typhoid fever; the paths and channels by which the infectious germs are communicated; the value of the Widal test; the importance of watching the urine for typhoid bacilli; the need and methods of eliminating typhoid germs from the urine when found; the necessity for sending to the Board of Health prompt and accurate reports of cases of typhoid fever; disinfection; the purification of water and sewage and the disposal of garbage and other municipal wastes.

From the first the physicians coöperated with the health board in a most encouraging and helpful manner. It is largely due to the help thus received that the work of the Board of Health was

successful and the number of cases of comrade or house infection was kept small.

The Chamber of Commerce and various other less prominent bodies entered cordially into the work. The Chamber, in fact, had been largely instrumental in causing the sanitary campaign to be undertaken.

The officers of the St. Regis Paper Company of Deferiets placed themselves under the direction of the Board of Health and carried out in the village surrounding their plant a careful plan to exclude infectious matter from continuing to enter their sewers which flowed into the Black River.

Charles F. Bingham, mayor; John B. Rogers, president of the Board of Health; Dr. E. S. Willard, health officer; and Mr. Theodore Ely Knowlton, representing the Chambei of Commerce, were indefatigable in giving personal attention to the work. To all the employees of the board credit is due for services of an unusually arduous nature; it is impossible to name all, but a special word of appreciation belongs to E. J. DeLong, principal office assistant.

DISCUSSION.

The President. The paper is now before the Association for discussion. Perhaps Dr. Sedgwick will speak to us first.

Prof. William T. Sedgwick.* Mr. President and fellow members: It has been said repeatedly that the human race does not seem able to learn by recorded experience. It has got to suffer and learn by its own repeated and individual personal experience. And it seems to me that this epidemic wonderfully illustrates that point. The date of the epidemic was comparatively recent; and ever since 1885, when the great typhoid epidemic took place at Plymouth, Pa., it had been as clear as daylight to anybody that it was not wise to drink polluted water. Nevertheless, here was one of the proud cities of New York which continued to do that in full face of all the danger that must necessarily be connected with drinking it. It was apparently necessary for that city to sacrifice a lot of lives in order to be brought to the point of cleaning up its water supply.

There is nothing peculiar to Americans in this. It was the same

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in Hamburg in 1892. Hamburg had long been using a highly polluted water; typhoid was very high, and other diseases were abnormally high; but it took an epidemic of Asiatic cholera of international fame to cause the introduction of a purified water supply into that city. It seems to be a characteristic of civilized man everywhere that he is not able to learn by recorded experience.

We are having the same sort of experience with our schoolhouses to-day. It took the sacrifice of one hundred and sixty children in the central part of the country to teach school boards everywhere that it was important to look out for exits from schoolhouses and to have fire drills rightly conducted. I suppose to-day the lives of all school children are infinitely safer with respect to fire than they were a month ago, because of the sacrifice of these victims.

The moral of all these things is that we need to keep high standards in water supplies, and in every branch of civilized life; that we need better administration, we need higher moral tone among those charged with public responsibilities. And I believe that this Association has long stood for that higher tone. I believe there is not a member of it who, if supplying water under the conditions described by Dr. Soper, would not spend wakeful nights, and possibly even resign his position, rather than continue to supply water to his people in the face of dangers as grave as those which confronted Watertown. If there be any such man, it is high time he resigned his place. We have got to keep high standards in this matter, and I think we are all indebted to Dr. Soper for making that fact so clear to us. There is nothing new in the water pollution part of his story. We all know that it is the same thing which we have heard over and over and apparently have got to hear for many years to come, before we in America, and others in other parts of the world, learn that it is not safe even for one day to continue the consumption of a water exposed to serious pollution without first purifying that water and protecting it in some way.

Dr. Soper's great work has been in showing that typhoid fever ought to be treated as a contagious disease. If I am not mistaken, his work has been more thorough in this respect than that of any member of this Association, and probably of any other man in this country. And it was also early work. In his very effective

measures applied at Ithaca, and repeated here at Watertown, he has shown from the start a logical mind in that he has been led to carry through to the uttermost the obvious measures which were required to drive typhoid fever out of a community; and I know of no one who has been so painstaking and so thorough in this respect.

It happens that his work is just now extremely timely because, owing to the emphasis at present laid upon typhoid carriers, and for various other reasons, mainly bacteriological, which I need not stop to detail, the world is waking up to the fact that typhoid fever ought to be treated as a contagious disease. And here again we have to say that we have been very slow, all of us, and perhaps reprehensible even, in having put off so long the recognition of this fact, and the pushing of it to its logical conclusions, for the moment we examine the history of typhoid fever we find that from the very beginning it was recognized by many who investigated it to be a highly contagious disease.

We water-works people, however, are to be pardoned in large measure in this direction, because physicians have for a long time been in the habit of saying, when called to a family having typhoid, and when questioned as to the danger for the other members of the family, " You need have no fear; typhoid is not a contagious disease, it is only infectious." These physicians were in the wrong, as we know to-day, and as we might have known for a good while if we had only given heed to the best of physicians. It is a curious and interesting fact that when typhoid was first worked out in 1829, and separated from jail fever and ship fever and the other forms of typhus fever with which it was previously confounded, — I say it is an interesting and it has been an unfortunate fact, that a large part of the differentiation between the two was made to consist in the fact, or the alleged fact, that typhus fever, the old-fashioned jail and ship fever, is contagious, while typhoid is not. Now in a very rough and rude way that is true. Typhoid is not as contagious as typhus is, and it is not as contagious as smallpox or scarlet fever or as a good many other of the so-called and admittedly contagious diseases. But owing to the emphasis laid upon this differential point between the two diseases, physicians themselves took the ground that typhoid was comparatively

non-contagious and typhus comparatively contagious; and, as time went on, the idea was spread abroad, very naturally, that typhoid is not contagious, and physicians generally have thought so and have said so over and over again. Whereas, the truth is this: Typhoid is not as contagious as many other diseases, but it is truly contagious, nevertheless. It is a contagious disease, and it is a matter of satisfaction to me, and must be to every one who has treated it as such for a number of years, that some of us, at any rate, have said so, and were in print years ago as having insisted on that fact.

Now Dr. Soper, fortunately free from traditional prejudice in this matter, and following up the logical conclusions drawn from bacteriology, no doubt, has from the outset acted as if typhoid is practically a contagious disease, and as if the way to fight it is to treat it as such; and in his work at Watertown and at Ithaca and elsewhere he has honored the water-works profession, and the laity, of which he is a member, by having acted up to his convictions. Therein lies his distinction, because some of the rest of us who have known the facts, perhaps just about as well, have not so acted, or, at least, have not acted to the same extent. And I am glad he showed you in somewhat elaborate detail his hospitals of various sorts, and that he has told in his paper of the pains taken to disinfect and to get rid of infection. This is most honorable to him as an engineer and as a member of the water-works profession. In doing this he has actually led the way for boards of health to-day. It required a man like him to teach the Watertown board of health how to handle an epidemic of this sort. And the same thing was true in Ithaca, I believe, and elsewhere.

We have here the rounded whole. We have the clear proof of water infection; we have then the scientific and logical following through to the uttermost of the consequences of that conclusion, with insistence upon such a treatment of the epidemic as is required by our modern knowledge. The bacteriological progress which has been made, and especially certain discussions in Germany, have shown that it is easy to find the causal germ in early stages of the disease. And boards of health are beginning to wake up to the fact that typhoid has got to be treated in every respect as a contagious disease. Though admitting that it is not as con-

tagious as some other diseases, it is still to all intents and purposes contagious.

From another point of view, work of this kind tends to shed light upon that residual amount of typhoid fever which remains in a community after the water supply is perfected. In the case of Washington, for example, I have no doubt that it will eventually turn out, as the editorials in *Engineering News* have encouraged us to believe, that a large part of the typhoid fever still lingering there, after the water has been thoroughly purified, will prove to be spread by ordinary, old-fashioned contagion. All of which is important for us as water-works men. If typhoid fever in Washington remains high after a good filter is introduced, discredit falls perforce upon the filter. We need to know about this residual typhoid; we need to know what causes it, and if by proper disinfection and proper treatment, such as Dr. Soper has so very well outlined, we are able to reduce typhoid fever in any community to zero, or very nearly to zero, as I believe we shall be able to do when once these processes of disinfection have been installed, then the work will be of value not only as a lesson to boards of health, but as serving to protect those of us who are interested primarily in pure water. In more than one instance it has turned out that the purification of the water supply has not adequately diminished typhoid fever in the city affected, and one of the reasons is, apparently, a lack of this very thoroughness, this masterly grasp of details, which Dr. Soper has shown can be made effective, and which he was one of the first to display. It is for this reason, it seems to me, that the paper is of special value and of much timeliness, and I, for one, feel greatly indebted to Dr. Soper for his careful presentation of it here and now.

Prof. C.-E. A. Winslow.* Dr. Soper's account of the Watertown epidemic has interested me greatly and I am sure that others must feel, as I do, gratified that he should have reported his investigations through the medium of the New England Water Works Association. We have all of us grown to look with the pleasantest anticipations to Dr. Soper's visits to Boston, for he has always something to tell us which we want to hear.

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The Watertown case as presented to-day appeals to me particularly as an indication of the new attitude which sanitarians are rightly adopting toward typhoid fever. Here is primarily a water-borne epidemic, and yet most of Dr. Soper's paper has dealt with preventive measures which have nothing to do with water supply. This means that the views which Professor Sedgwick and I had the honor to present to this Association in 1906 * have gained general acceptance to-day and that sanitarians now realize that water is only one factor in the causation of typhoid fever. In many communities this disease has no relation whatever to water supply, and even where polluted water is the prime cause, its influence is multiplied and extended by a host of other channels of infection.

The water-borne typhoid is easy to deal with. Cities which continue to drink sewage do so with their eyes open or in willful and deliberate ignorance. The factors which produce prosodemic typhoid, on the other hand, typhoid which spreads from person to person by various vehicles, are much more obscure and less easy to control. It is fortunate that in this particular case the authorities of Watertown atoned for their early neglect by prompt remedial measures after the epidemic of 1904. It is significant that in so doing they did not content themselves with retaining the ablest engineering talent in connection with purer water, but called in also our guest of the afternoon, who has made a national reputation as a specialist in the eradication of residual typhoid.

It is this prosodemic or residual typhoid which now constitutes the great bulk of the disease in the United States. Even in Watertown since the filtration of the water supply it still causes excessive death-rates, according to Dr. Soper's figures. Rates of 50 per 100 000 in 1906, and of 37 per 100 000 in 1907, demand some explanation. The truth is, we are only at the beginning of our knowledge of typhoid fever, in spite of the fact that probably no disease except tuberculosis has received so much attention. There is one factor in particular to which almost no attention has hitherto been paid, but which I am inclined to think is soon to receive a new share of attention, and this is the varying predisposition of the

* Journal, March, 1906, Vol. XX, p. 51.

host. I should like to occupy a moment in calling your attention to this neglected point.

It is well known that typhoid fever, where not due mainly to polluted water, follows the curve of temperature with remarkable closeness. Recent investigations at Washington and at Youngstown, Ohio, have shown this with great clearness, and the phenomenon appears to be a universal one all over the world. Comparing different geographical areas, too, it is well known that typhoid on the whole is most prevalent in warm climates, but I did not myself realize how close this relation was until I analyzed, a day or so ago, the census returns for the Atlantic states according to their geographical position. As indicated in the table below, the typhoid rates for the white population average in the North Atlantic states about 30 per 100 000, and, with the exception of Pennsylvania, lie between 17 and 31; Pennsylvania's high rate of 44 is, of course, due to the large quantity of polluted water which was consumed in that state in 1900. The second group of states from Ohio to North Carolina shows an average death-rate of 54, and the individual rates range from 42 in Maryland to 76 in Kentucky. Finally the southeasterly and Gulf states show an average death-rate of 81, with individual variations from 57 in Florida to 93

TABLE V.

Typhoid in the Atlantic States in Relation to Latitude.

Death-rate per 100 000. Among whites only.

(United States Census for 1900.)

Northern Group.		Middle Group.		Southern Group.	
State.	Typhoid Rate.	State.	Typhoid Rate.	State.	Typhoid Rate.
Maine,	29	Ohio,	43	Tennessee,	84
New Hampshire,	17	Maryland,	42	South Carolina,	72
Vermont,	31	Delaware,	53	Georgia,	80
Massachusetts,	22	Dist. of Columbia,	69	Florida,	57
Rhode Island,	24	West Virginia,	62	Mississippi,	87
Connecticut,	27	Virginia,	48	Louisiana,	71
New York,	25	Kentucky,	76	Alabama,	93
Pennsylvania,	44	North Carolina,	70		
New Jersey,	21				
Group,	30	Group,	54	Group,	81

in Alabama. Of course such gross death-rates as these are affected by many other factors than temperature. The water supplies in individual cases are worse than in others, but on the whole I think there can be no doubt of the general lesson to be drawn from this table. Pennsylvania, with its heavily polluted water supplies, is found, it will be noticed, in the northern group, and the District of Columbia in the middle group. There seems no escape from the conclusion that there is a striking direct relation between temperature and the prevalence of typhoid fever.

In reviewing the question of seasonal prevalence in 1902, Professor Sedgwick and I were inclined to explain the autumn maximum as follows:

"The bacteriology and the etiology of typhoid fever both indicate that its causal agents cannot be abundant in the environment during the colder season of the year. The germs of the disease are carried over the winter in the bodies of a few patients and perhaps in vaults or other deposits of organic matter where they are protected from the severity of the season. The number of persons who receive infection from the discharges of these winter cases will depend, other things being equal, upon the length of time for which the bacteria cast in these discharges into the environment remain alive and virulent. The length of the period during which the microbes live will depend largely upon the general temperature; as the season grows milder, more and more of each crop of germs sent at random into the outer world will survive long enough to gain entry to a human being and bear fruit. The process will be cumulative. Each case will cause more secondary cases; and each of the latter will have a still more extensive opportunity for widespread damage. In our opinion the most reasonable explanation of the seasonal variations of typhoid fever is a direct effect of temperature upon the persistence in nature of germs which proceed from previous victims of the disease."

My own confidence in the theory that the seasonal prevalence of typhoid is due to the effect of temperature upon the germ alone was somewhat shaken by a study of the admirable report upon the origin and prevalence of typhoid fever in the District of Columbia by Dr. Rosenau and his associates, published by the Hygienic Laboratory of the Public Health and Marine-Hospital Service. It appeared that in 1906 the typhoid curve did indeed follow in general the relation of the temperature, but that its greatest rise was not gradual but sharp, coinciding with the period of extreme hot

weather in the middle of July. The conception of the seasonal curve as due to the action of temperature upon the germ in the environment presupposes a very gradual change, and it is difficult to see how a sudden period of hot weather could produce a sudden reaction. If, on the other hand, the temperature affects typhoid incidence in part by a direct lowering of the vital resistance of the host, such a phenomenon might be expected. I have recently come upon striking confirmatory evidence of this latter theory. An extremely suggestive monograph on enteric fever in India has recently been published by Major Ernest Roberts of the Indian Medical Service (Calcutta: Thacker, Spink & Co., 1906). In this most important contribution to the etiology of typhoid fever, Major Roberts emphasizes his own belief in the importance of the vital resistance factor in the spread of typhoid. As he puts it: "Both host and parasite are definitely subject to the influence of the environment as it produces any seasonal changes; that both live and thrive by adaptation only; and that the problem of acclimatization or colonization is the same for both, — a contest for supremacy by immigrant races." The most striking evidence which Major Roberts adduces for the support of this view is included in the following table which shows that whereas the typhoid among the European troops in India follows the general rule and is concentrated in warm weather, that in the native troops follows an exactly reverse course. This seems difficult to explain on any theory of germ distribution. If germs are most abundant in warm weather they should affect both English and natives at that time. If, on the other hand, the relation of temperature to vital resistance of the host is a prime factor, we might expect just such a relation as is indicated in the table. Certainly English troops must be much more affected by the hot weather of India than the natives, and it is possible that the natives may in their turn be unfavorably affected by the colder season in many parts of the peninsula.

TABLE VI.

PERCENTAGE OF TOTAL MORTALITY.

	Hot Season. (May to Oct.) Per Cent.	Cold Season. (Nov. to April.) Per Cent.
European troops	62	38
Native troops	37	63

It seems to me clear that we have in the etiology of typhoid to reckon with three factors: First, the number of active germs present in the environment; second, the vehicles, water supply, milk supply, filth, etc., available for transmission of germs to the patient; and third, the vital resistance of the patient himself. It is perfectly possible according to this theory for an individual in good health to receive typhoid germs without succumbing to the disease, just as we know to be the case in tuberculosis and other disorders of the respiratory tract. A period of extreme hot weather, on the other hand, either by direct effect on the organism or through favorable indirect influence on fermentations in the digestive tract, upsets the defensive mechanism of the alimentary canal and we get a sudden sharp increase of typhoid fever. This, without in any way excluding the direct effect of temperature upon the germ in the environment, helps to explain the prevalence of fall fever and the increase of typhoid in warm climates. It helps also perhaps to explain the general excess of typhoid fever in this country as compared with that which obtains in northern Europe. It still remains true that a very large amount of the typhoid which exists in this country constitutes a national reproach. The prospects for the future, however, are bright and we may look to see residual typhoid wiped out in the future as water-borne typhoid is rapidly being eliminated to-day. When this is done it will be by just such forceful and thorough and painstaking campaigns as that which Dr. Soper has carried out at Ithaca and Watertown.

Mr. George C. Whipple * (*by letter*). The writer has been interested in reading Dr. Soper's paper, partly because of his general interest in the subject of epidemics and their relation to public water supplies, and partly because he is familiar with the present conditions in Watertown. From the facts which have been so ably presented many important lessons may be drawn. Some of these have been already mentioned by Professor Sedgwick and others. The more that epidemics of typhoid fever are studied, the more sanitarians are coming to appreciate the fact that this disease is contagious as well as infectious. In every large epidemic many of the cases, especially the late cases, are

* Consulting Engineer, New York City.

caused not by the original infection, but, as we say, by "secondary infection," that is, by direct contagion from early cases. This was strikingly shown in the typhoid fever epidemic that occurred in Gelsenkirchen, Germany, a few years ago. This epidemic was caused by an infection of the public water supply, but a careful study of the situation showed that a large proportion of the cases that developed near the end of the epidemic were due to contagion. This is interestingly shown by the following diagram, Fig. 11.

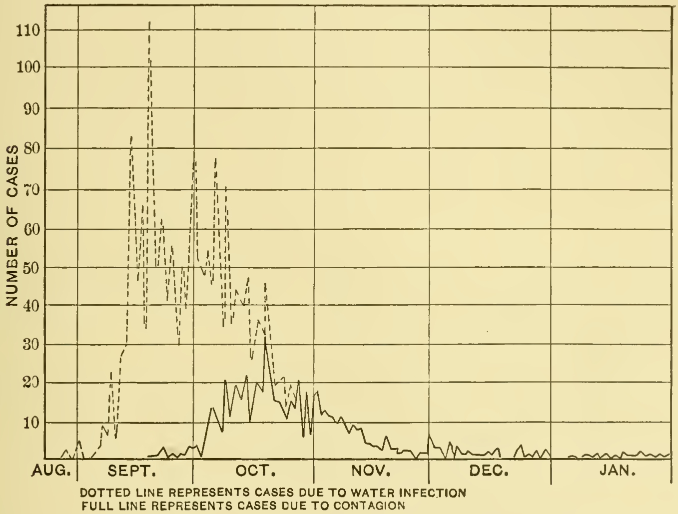


FIG. 11. DIAGRAM SHOWING THE PROGRESS OF THE TYPHOID FEVER EPIDEMIC IN GELSENKIRCHEN, GERMANY.

It was the prevention of these cases of secondary origin to which the work of Dr. Soper in Watertown was chiefly directed. How far he was successful in accomplishing the result cannot be definitely shown from the data presented, but there is no reason to doubt that many lives were saved by the sanitary reforms that were inaugurated under his direction.

It was unfortunate for the city that more stringent measures to quell the disease were not taken earlier in the history of the epidemic. The long duration of the epidemic shows that the water supply must have been in a continually infected condition for many weeks, as the city had but a small storage reservoir and

the water was pumped for most part directly into the mains. Apparently the measures taken to avoid the secondary cases were more elaborate and probably more effective than those taken to do away with the infection of the river water. The early history of the epidemic is an illustration of the procrastination which so frequently occurs even in the most intelligent communities. Apparently the epidemic had been running for nearly a month before any active measures were taken to get control of the situation. It would seem as if the occurrence of more than twenty cases during the first three days of January would have been followed by an immediate investigation. In these matters, however, the city of Watertown is not very different from other communities, nor can it be claimed that the officials were more lax than they are in most cities. In all health departments there is a tendency to regard the reported cases of infectious diseases as facts for history rather than as facts for prophecy. Such data are valuable for purposes of record, but they are far more valuable as indications of what is likely to happen in the immediate future. Unless the data reported by physicians are carefully studied from this point of view they lose a large part of their value.

Of the methods used by Dr. Soper in checking the epidemic little need be said, as they speak for themselves. The ways in which the typhoid fever germ is transmitted are now pretty well understood, and the methods of preventing these germs from finding their way from some patient to a new victim are pretty well known by water-works men, and have been the subject of repeated discussion in this Association. The writer is inclined to think that up to the present time too little attention, perhaps, has been given to the barriers that should be established to prevent the scattering of the germs from the patient; that is, to disinfection. The stamping out of this disease can only be done by coöperative work, in which physicians, nurses, engineers, and many others play a prominent part. In order to illustrate this fact the writer has made use of the simple diagram which is here presented, Fig. 12.

Mention has been made of the fact that a filtration plant was put in operation in Watertown in 1904.

Since the introduction of this filtration plant the typhoid fever

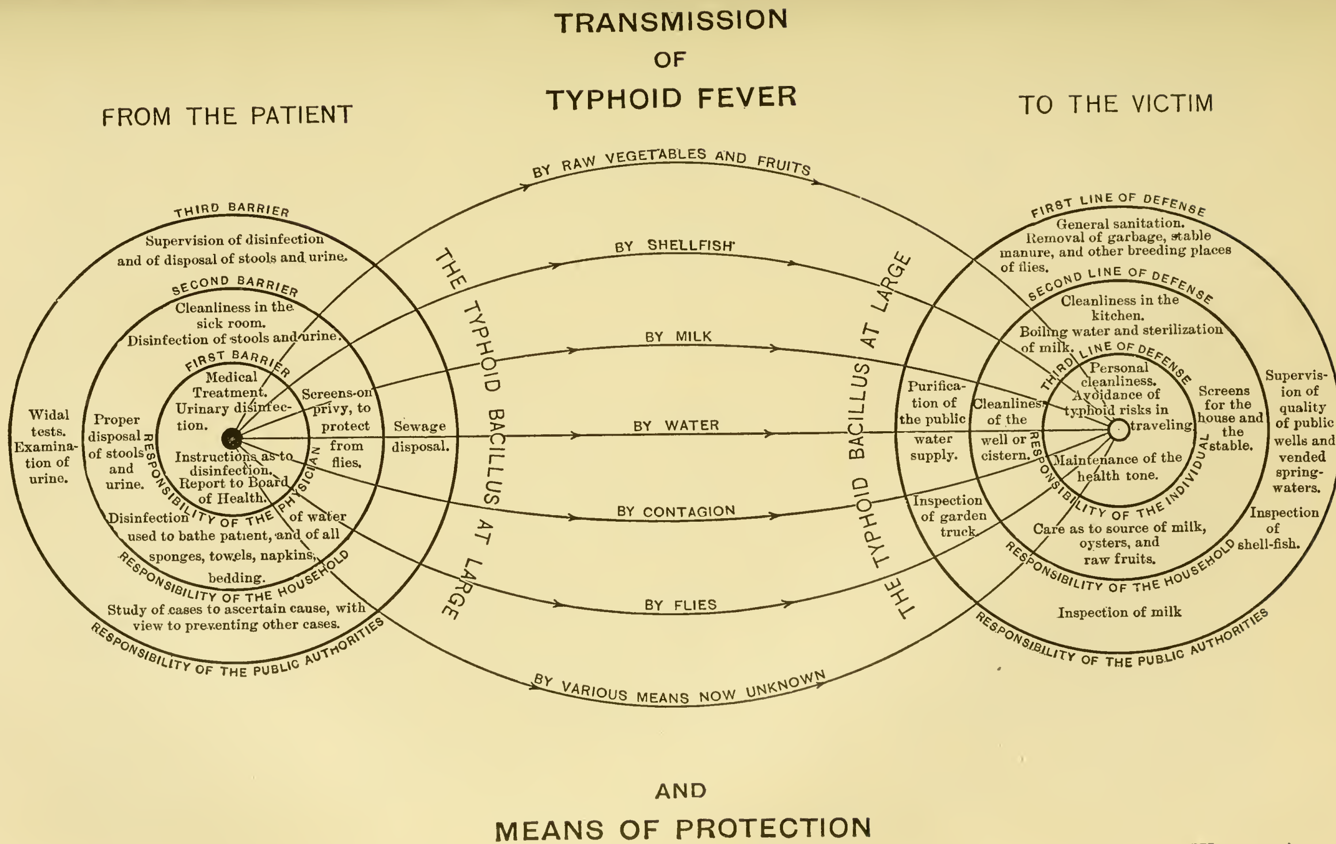


Fig. 12. (From "Typhoid Fever: Its Causation, Transmission, and Prevention," by George C. Whipple.)

death-rate has been very materially decreased. It has not fallen quite as low, however, as it has in some other cities after the water has been subjected to purification. This has been due partly to the occurrence of cases apparently caused by contagion, as many of them were located near the outskirts of the city where there was no water supply; partly to the importation of cases that developed elsewhere; and partly, perhaps, to the existence of private water supplies for fire purposes in a number of mills that are connected with the city mains and provided with the usual check valves. The water for these fire supplies is taken from the river in the heart of the city and is obviously open to pollution. No direct evidence has been obtained that these mill supplies have been actually the cause of any cases of typhoid fever, but in view of the fact that such connections have caused trouble elsewhere, it cannot be denied that they are a source of danger, or that they may have played some part in the continuance of typhoid fever in Watertown. Certain it is, however, that the filter plant has shown a hygienic efficiency that compares well with similar filters elsewhere. The filter plant is in charge of a trained chemist and bacteriologist who very regularly and frequently makes analyses of the water before and after filtration. As this filter has not been described to the members of this Association I have taken the liberty of inviting Mr. F. H. Jennings, the chemist in charge of the plant at the present time, to contribute to this discussion a statement covering the operation of this filter since its installation in 1904.

Mr. F. H. Jennings * (*by letter*). It would be interesting to compare analyses of the Black River water as supplied to Watertown in the winter of 1903–4, if they were available, with analyses made subsequent to that time, especially the bacteriological analyses. The raw water counts obtained at the city filtration plant in Watertown in the months of December, January, February, and March show only moderate numbers of bacteria in the winters of 1904–5 and 1905–6, but much higher numbers in the winters of 1906–7 and 1907–8, as shown in the following table. The counts obtained in the summer months did not show a corresponding variation, though the counts obtained in the summer months

* Superintendent of Filtration Plant, Watertown, N. Y.

of 1907 were rather higher than in the preceding summers. At the same time, the positive presumptive tests for colon in one cubic centimeter samples of the raw water were more frequent in the winters when the counts were low than when they were high, averaging for the winter of 1904–5, 94.5 per cent., and for the winters of 1906–7 and 1907–8, 41.5 per cent. of the tests made.

TABLE VII.

Bacteria in Black River Water at Watertown, N.Y.

		1904.	1905.	1906.	1907.	1908.
January	Average		7 480	2 721	64 150	23 900
	Maximum		27 700	12 600	18 900	49 200
February	Average		2 200	2 033	21 410	40 800
	Maximum		4 920	5 000	52 600	138 300
March	Average		7 800	3 950	66 470	
	Maximum		30 900	17 000	134 100	
December	Average	2 960	708	39 800	30 480	
	Maximum	16 500	5 300	59 500	71 800	

A preliminary survey of the watershed made in the spring of 1907, covering sixty miles of the river above Watertown, in an effort to locate some specific cause of these higher counts, showed that they were general on the main stream and all the principal tributaries. During the winter of 1906–7 there was comparatively little snow, but during the winter just passed the snow was deep all over the Black River country. The general temperature was about the same in the two winters, so we could find no explanation of the higher counts in climatic conditions. During both winters the river was completely frozen over.

The chemical and physical characteristics of the water also vary widely. There are a number of paper and pulp mills on the river above Watertown, both chemical and mechanical processes being used. The effect of the chemical waste is quite apparent in times of low water in the river. A change of color of twenty-five parts per million (platinum scale) in four hours is not unknown here. This may mean an increase of 30 per cent. in the color in four hours. This color change is frequently accompanied by a decrease in the alkalinity of the raw water.

Since the installation of the filtration plant there has been a marked reduction in the typhoid death-rate, as shown by Table I in the paper under discussion, and a still more marked reduction in the typhoid morbidity rate, as is shown by the following table based on figures obtained from the annual reports of the local health officer:

TABLE VIII.

Year.	Population.	Cases of Typhoid.	Cases per 100 000.	
1900	21 696 (census)	193	877	
1901	22 400 (estimate)	150	670	
1902	23 200 ,,	306	1 319	
1903	23 900 ,,	231	967	
1904	25 000 ,,	703	2 812	(Epidemic year. Filter plant in operation September 12.)
1905	25 447 (census)	108	424	
1906	27 500 (estimate)	130	473	
1907	30 000	103	343	

In considering the morbidity rate it should be remembered that Watertown is the center of a large district having no hospitals except those in Watertown, so that a considerable proportion of the cases reported are imported,—brought to the local hospitals for treatment and reported from there. For instance, in 1907, the only year for which I have the figures, there were 20 such cases, or 19.4 per cent. of the total cases reported. If these 20 cases be deducted the morbidity rate becomes 277 instead of 343.

I know of no local explanation of the higher mortality and morbidity rates for 1906 than for the other years since the filtration plant was established. I understand that typhoid was more prevalent than usual throughout northern New York in 1906, so it seems to have been a general condition rather than a local condition.

Previous to the installation of the filtration plant high monthly typhoid morbidity rates were rather general, occurring at no particular season; but since the installation of the plant the high morbidity rates have occurred in the fall months, when other causes than water supply are most active, as shown in Table IX.

The filtration plant in Watertown has been in operation now about three and one-half years, and it may be of interest to consider

TABLE IX.

CASES OF TYPHOID BY MONTHS.

Month.	1902.	1903.	1904.	1905.	1906.	1907.	1908.
January	13	23	180	7	7	18	2
February	16	47	302	4	10	7	3
March	37	29	101	17	4	8	
April	30	18	31	7	6	7	
May	26	3	19	3	2	6	
June	18	9	3	0	1	9	
July	22	23	11	3	3	0	
August	28	22	3	8	15	9	
September	39	21	21	12	26	15	
October	30	14	13	20	26	15	
November	20	7	14	10	18	3	
December	27	15	5	7	12	6	

the operation a little more in detail. The figures given in the following tables show this clearly. These figures are in all cases the monthly averages obtained from the records kept at the filtration plant. Table X shows the principal water quantities for the period.

During the winter of 1904–5 the water consumption was very high owing to leakage and waste, largely the latter. A campaign against this waste resulted in a lower consumption, but as the city grows larger the consumption is going up again, so that there have been times this last winter when it was difficult to keep up the supply of filtered water.

It will be noticed that during the last three months for which figures are given above, the period of service has been longer than usual; in fact, it has been necessary to make a rule that the filters should be washed at the end of forty-eight hours whether or not there was need of it to keep up the supply of filtered water. We ordinarily wash when the water falls to a certain level in the clear water well, experience having shown that, with us, this is better than washing at a certain loss of head on the filters.

The low values for the amount of water filtered between washings in the months of June, July, August, and September, 1907, were due to difficulties in the operation of the plant ensuing from the low stage of the river.

TABLE X.

Month.	Amounts of Water Filtered in Million Gallons per Day.	Percentage of Wash and Waste Water.	Number of Filters Washed Daily.	Period of Service in Hours.	Amount of Water Filtered between Washings, in Million Gallons.
1904.					
October....	4.418	6.7	12	15.40	0.371
November..	4.622	3.6	8	24.58	0.575
December..	5.250	3.8	11	18.59	0.475
Average .	4.760	4.7	10	19.52	0.473
1905.					
January ...	5.458	3.2	8	21.57	0.674
February ..	6.090	4.6	15	13.62	0.409
March	4.980	4.2	12	16.45	0.417
April	4.157	3.0	6	27.91	0.643
May.......	4.322	3.8	10	18.38	0.432
June.......	4.662	4.6	11	17.63	0.457
July.......	4.541	3.9	7	20.05	0.428
August	4.296	5.3	11	16.81	0.414
September .	4.283	3.4	7	25.04	0.568
October....	3.797	3.5	7	21.26	0.546
November .	3.909	3.7	7	25.96	0.548
December..	4.234	3.3	7	26.37	0.601
Average .	4.561	3.9	9	20.92	0.512
1906.					
January ...	4.302	3.3	7	26.95	0.617
February ..	4.326	3.2	7	26.17	0.617
March	4.274	3.1	7	24.49	0.602
April	3.850	2.8	5	29.79	0.749
May.......	3.282	3.2	7	24.43	0.653
June	4.177	4.3	9	22.56	0.595
July.......	4.184	4.5	10	20.04	0.501
August	4.096	4.5	10	20.91	0.495
September .	4.058	4.3	9	23.77	0.526
October....	3.793	3.8	7	24.59	0.563
November .	3.485	2.5	5	39.98	0.726
December..	4.108	2.9	6	29.46	0.773
Average .	3.995	3.5	7	29.10	0.618
1907.					
January ...	4.142	2.3	5	33.66	0.942
February ..	4.908	2.9	7	26.18	0.782
March.	5.219	3.5	10	19.19	0.605
April.	4.630	2.6	7	28.93	1.079
May.......	4.536	3.0	8	26.31	0.700
June.......	4.534	4.0	9	22.73	0.474
July.......	4.530	5.3	12	15.95	0.356
August	4.743	4.9	13	13.42	1.355
September .	4.493	5.4	13	13.49	0.342
October....	3.910	3.6	7	22.07	0.528
November .	3.482	2.7	5	32.36	0.763
December..	3.887	2.2	3	47.79	1.217
Average .	4.418	3.5	7.6	25.17	0.679
1908					
January ...	4.214	2.9	4	43.12	1.117
February ..	4.910	2.2	5	37.06	1.063
Average .	4.562	2.55	4.5	40.09	1.009

Table XI shows the amounts of coagulant used and effect of filtration on the water.

Our highest raw water colors occur in the summer and autumn when the river is lowest, and at these times the color is also subject to considerable variations, necessitating careful watching of the raw water and regulation of the amount of alum used. The maximum raw water color (day's average color) was 140, and the minimum, 38.

The turbidity of the raw water is, as a rule, low. One day has shown a turbidity of 200. The minimum was 1; the average since the plant has been in operation, 10.

The alkalinity of the raw water has varied widely from a maximum of 80 to a minimum of 14. In 1905 the average raw water alkalinity was 39; in 1907 it was 28. There are, at times, from 1 to 5 parts of "suspended alkalinity" in the water, the exact source of which we have not been able to learn. In the earlier years of the operation of the plant it was never necessary to add alkalinity to the water except for a week or so in the spring when the snow was going off, but in 1907 it was necessary to add alkalinity (soda-ash) during parts or all of seven months — March, April, and May in the spring, and September, October, November, and December in the fall and winter.

It will be noticed that the amount of coagulant was increased greatly in the winters of 1906–7 and 1907–8. This was due to the greatly increased number of bacteria in the raw water as shown in Table VII. Ordinarily sufficient alum to reduce the color to a satisfactory amount, below 10, is more than enough to guarantee the hygienic efficiency of the plant, so that we can regulate our alum feed according to the color of the raw water.

From the time the plant was put into operation until the first of March, 1908, there have been tested at the plant 14 474 samples of water, including about two hundred fifty samples analyzed in connection with investigations of the pollution of the river. Samples of raw and filtered water are taken every four hours throughout the twenty-four for chemical and physical tests. Bacterial analyses are made daily except Sunday. These show that the bacterial efficiency of the plant is good and that the removal of coli is general also.

TABLE XI.

Month.	Color.		Turbidity.		Alkalinity.		Coagulant Used.	
	Raw.	Filtered	Raw.	Filtered	Raw.	Filtered	Pounds per Million Gallons.	Grains per U. S. Gallon.
1904								
Oct.	103	15	18	0	28	14	376	2.63
Nov.....	64	7	7	0	31	17	257	1.80
Dec.	51	8	4	0	35	19	242	1.69
Av....	72	10	9	0	31	17	291	2.04
1905.								
Jan.	53	8	5	0	40	24	238	1.67
Feb.....	47	9	3	0	35	19	234	1.64
March ..	44	10	12	0	37	21	261	1.83
April....	57	6	22	0	23	9	244	1.71
May	67	11	5	0	28	14	240	1.68
June....	90	14	14	0	33	15	309	2.16
July	104	13	8	0	36	14	379	2.65
Aug.....	82	16	9	0	42	19	358	2.51
Sept. ...	80	11	9	0	42	17	352	2.46
Oct.	80	9	9	0	47	20	351	2.46
Nov.....	77	10	8	0	49	22	349	2.41
Dec.....	52	9	8	0	56	34	242	1.69
Av....	69	11	9	0	39	19	296	2.07
1906.								
Jan.	51	7	23	0	54	37	257	1.80
Feb.....	48	10	9	0	44	28	260	1.82
March ..	42	6	13	0	41	25	259	1.81
April....	44	3	16	0	33	22	235	1.64
May	51	8	12	0	29	22	215	1.50
June....	73	10	11	0	34	23	300	2.10
July	87	9	9	0	38	24	346	2.42
Aug.....	79	11	5	0	42	22	364	2.55
Sept.....	75	9	2	0	27	9	356	2.49
Oct.	74	13	7	0	34	17	322	2.25
Nov.....	64	9	18	0	36	20	322	2.25
Dec.	60	7	9	0	35	19	323	2.26
Av....	62	9.5	11	0	37	22	297	2.11
1907.								
Jan.	56	4	22	0	29	11	325	2.26
Feb.....	45	4	8	0	29	10	361	2.53
March ..	47	1	19	0	29	9	414	2.90
April....	56	0	22	0	27	18	363	2.55
May	61	0	10	0	29	12	364	2.55
June....	65	2	5	0	29	11	348	2.44
July	87	8	3	0	30	11	358	2.51
Aug.....	84	14	6	0	33	13	354	2.48
Sept	89	12	7	0	30	10	365	2.56
Nov.....	87	7	12	0	24	11	363	2.56
Dec.....	71	5	14	0	28	15	366	2.57
Av....	69	5	11	0	28	12	362	2.53
1908.								
Jan.	54	1	4	0	30	14	358	2.51
Feb.....	56	4	9	0	29	13	376	2.64
Av....	55	2.5	6.5	0	29.5	13	367	2.57

Full records of the operation of the plant are kept. The filter attendants are required to keep an hourly record of the amount of coagulant used, the quantity of water entering the plant, the amounts of water in the coagulating basins and clear water well, the losses of head on the individual filters, and full details of all washings of the filters. These are all checked up daily by the superintendent of the plant, who also keeps records of all water quantities passing through the plant, the amounts used in washing and waste, the amount of water pumped into service, the amounts of water on hand at the end of the day in each of the various basins, the amounts of coagulant used and on hand, and full records of the bacteriological, chemical, and physical tests made on the water.

Besides the superintendent there are three filter attendants, each working an eight-hour day.

The plant also possesses an alum storehouse capable of holding six months' supply of alum if need be. This was deemed advisable as the rigor of northern winters sometimes interferes materially with freight traffic.

The cost of operation of the plant since it started has been as given below in Table XII.

TABLE XII.

Chemicals	$13 924.52
Salaries and supervision	12 607.55
Repairs, new sand, extra labor, grading, and new construction	1 889.05
Coal	1 102.83
Freight, cartage, and miscellaneous	1 035.45
	$30 559.40

This makes the cost of filtration per million gallons, without allowing for depreciation and interest on the capital invested $5.57.

Dr. E. S. Willard * (*by letter*). I have not had an opportunity to read this paper carefully, but from my knowledge of Dr. Soper and his work I have no doubt that the epidemic and the campaign against it have been accurately described. This is, in fact, the only account of the outbreak which has appeared, so far as I know.

It may be of interest to state that the general course followed by the city of Watertown in its crusade against the fever was in

* Health Officer, Watertown, N. Y.

accordance with a suggestion made by Dr. Soper himself several months before the epidemic broke out. When we first realized that an epidemic might be upon us and that extraordinary measures might be necessary to put a stop to it, I remembered a paper which I had heard read at the third annual conference of Health Officers of New York State, at Albany in October. The title of this paper was "The Management of Typhoid Fever Epidemics," * and it was delivered by Dr. Soper soon after he returned from the typhoid epidemic at Ithaca.

Many of the steps which should be taken to put a stop to an epidemic of typhoid were described in the paper. It was pointed out, however, that the details suited to every situation could not all be described and that the best thing for a local board of health to do in case of epidemic was to call on the state for an expert to come and direct the sanitary campaign. If the state could not supply such a person, an outside expert should be called upon. To quote from the address, Dr. Soper said:

"I am aware that in expressing an opinion favorable to what may be considered a state management of epidemcis I am recommending a course which appears to be different from that ordinarily followed in this commonwealth. But the difference is more seeming than real. It has been the custom on occasions of severe epidemic for the State Department of Health to send a representative to investigate the cause of the trouble and to recommend measures for the elimination of the cause. The visit of the expert has usually been brief, two or three days ordinarily being considered sufficient for his investigation.

"The suggestion that I make is that the state send a representative to remain long enough at the seat of epidemic to insure the adoption of measures which will bring it under control, whether this takes three days or three months."

When the epidemic began at Watertown, the State Department of Health was informed that typhoid was prevalent and a question was asked as to what, if anything, should be done about it. In response to this appeal the state sent Professor Landreth, who made an investigation into the cause of the epidemic and gave much good advice but whose other duties would not permit him to remain continuously at Watertown to fight the epidemic to a finish. There then remained the second alternative to consider,

* *Medical News*, New York, January 2, 1904.

namely, for the city to employ an independent expert. This was done by engaging Dr. Soper. He came within forty-eight hours and remained with us two months.

From first to last the relations between the state and local boards of health were cordial and, as far as the city was concerned, satisfactory. Dr. Soper acted in an advisory capacity, strengthening and supplementing the board with the results of his special training and experience and taking charge, as far as legal restrictions would permit, of a large amount of the executive work which was involved in carrying out his recommendations. The activities of the board were, of course, greatly increased in scope and number. No new laws or special ordinances were passed. The theory was that there would be enough sanitary regulations to meet the case if those already enacted were properly enforced. After the campaign was over the board returned to its usual and customary operations.

Mr. M. N. Baker * (*by letter*). It seems a great pity that Watertown, Ithaca, and Butler did not have the services of Dr. Soper before instead of after their typhoid fever outbreaks. It is certainly to be hoped that the time is not far distant when communities of this size and larger will each and all have in their employ scientifically trained men of experience and tact who will constantly guard them against both epidemic and endemic preventable diseases.

The slowness of both the city and state authorities to act at the time of the Watertown outbreak seems almost unaccountable. The State Health Department was not called upon until January 30, after some two hundred cases of typhoid had been reported within the month. The representative of the State Health Department did not arrive in Watertown until February 8, and even then he seems to have done little but give some general advice, after which he hurried away, to go back later for another brief visit.

The local authorities seem to have made no use whatever of the rules for the protection of the water supply formulated by the State Health Department. Why not? Their failure in this respect, and the apparent failure of other communities to make any very great use of like rules, suggests the utter inadequacy of this plan

* Editor *Engineering News*, New York, N. Y.

for protecting public water supplies in the state of New York. In the case of so large a drainage area and so small a community as were involved at Watertown, it is perhaps too much to expect that local authorities could effectively protect themselves against pollution under such rules as were authorized by the New York statute; particularly in view of the fact that the expenses for removing or preventing pollution are placed upon the community whose water supply is to be benefited thereby.

An explanation from some source seems to be demanded of the high typhoid death-rates that have prevailed in Watertown since the filtration plant was put in operation. In the light of our present knowledge of such matters it would appear that other sanitary reforms than an improvement in the public water supply are greatly needed at Watertown.

Water-works officials ought to realize, as few of them yet seem to do, the importance of doing all in their power to see that local boards of health do some effective work in tracing each case of typhoid fever to its source of infection. If this were done many a water supply which has been otherwise put in question would be exonerated, and, far more important still, many lives would be saved.

Mr. Kenneth Allen * (*by letter*). A public calamity that affords so excellent an object lesson in the exposition of its cause and in the means taken to eradicate the evil and bring about far better conditions than previously existed may be looked upon, from one point of view at least, as a blessing in disguise. The reduction in the typhoid death-rate from an average in 1885 to 1903 of 71, and in 1904, 194 per 100 000, to 24, 50 and 37 per 100 000 the following years, is an index of the direct effect of the house-cleaning the city of Watertown went through, but the indirect effect with its saving of life in other communities is much greater.

In this connection the various means taken to disseminate knowledge concerning the epidemic and its control, by lectures and by inviting the coöperation of the Chamber of Commerce, the Department of Charities, etc., must have gone far toward stamping out the epidemic and in counteracting the unaccountable

* Division Engineer, Sewerage Commission, Baltimore, Md.

attitude of *laissez faire* which existed. It is difficult to so convince the average citizen of the necessity of boiling a suspicious drinking water that he will see to it that it is regularly done. And if, perchance, this point is gained, the chances are nine to ten that he will not insist on equally sterile water for washing dishes, brushing teeth, and drinking when traveling.

For this reason the supplying of pure spring water at a nominal cost during epidemics of this kind is a step of much importance, and should always be done when practicable. So, too, in the preparation and distribution of disinfectants, as " white liquid " and " blue liquid," with simple directions to facilitate their safe and effective use by ignorant persons, good judgment was shown.

The failure to profit by the warning of the epidemic of 1895, and the continued high typhoid rate, seem inexcusable, but in this Watertown has not shown herself different from the average community. In matters of this kind safety is only secured by the constant vigilance of some responsible authority having power to act. The most obvious person to be clothed with such authority is the health officer. But in cases of water supplies and stream pollution the offense is so often committed beyond the jurisdiction of the local authority that, as in this case, the state must be appealed to through its Board of Health, whose executive officer, as well as the local health officer, should have power to execute the laws and ordinances governing the offense without further resort to higher powers. Beyond this come in the questions connected with the pollution of interstate streams, as the Mississippi, Missouri, Ohio, Delaware, Susquehanna, concerning which disputes, if not amenable to arbitration, must be referred to some Federal authority. Such cases are becoming more and more frequent with increased densities of population, and it is quite possible they may be best handled in connection with the question of water transportation and water-power by a Federal commission independent of, but coöperating with, and coördinating the efforts of, the several departments of the government. Such a division of authority would be elastic, in harmony with the general theory of our government, and would at the same time avoid division of responsibility. Moreover, it is directly in line with the present development in many of our states.

In the Watertown case the ineffective legislation of 1896 is instructive. With laws no doubt in the main good, and with power to act, yet they were rendered inoperative by imposing an unknown but possibly very great cost on the commissioners to whom their execution was intrusted. That fatal provision blocked the way at once to any abatement of the offensive conditions, and it was only after these became alarming and the higher authority of the state stepped in that efficient results were secured.

Fortunately the city and state coöperated in harmony, the former paying the latter for sanitary work on the watershed above by special agreement. The more definitely the line of responsibility can be drawn, however, between state and local jurisdiction in such matters, the better, and it would seem as if this might be accomplished at least to a greater degree than exists at present.

Mr. Francis F. Longley * (*by letter*). Dr. Soper's interesting paper sets forth in admirable manner the facts regarding this virulent outbreak of the dread typhoid in Watertown. It is of especial interest to the writer because of his connection with the water department of that city in charge of the operation of the filters during the year following the epidemic herein described. The filters, which were in course of construction at that time, were finished and put in operation early in the following September. They are of the "mechanical" type, and were fully described in the columns of the *Engineering Record* of dates May 21 and 28, 1904.

In watching the typhoid fever situation in Watertown during the first year of operation of the new filtration plant, the writer was impressed with one unusual fact. That was, that the typhoid death-rate fell from an average of 83 per 100 000 to 24 per 100 000 in that first year, in marked contrast to the gradual fall in typhoid death-rates in many other cities after the complete or nearly complete removal of the source of infection in the water supply.

The question that naturally arises is, What was the cause of this clean-cut drop in the typhoid curve? Was it the purification of the water supply alone, or were there other large contributing causes? The advocates of pure water and of filtration would be glad enough to take the credit for it in its entirety, but may they

* Chief Chemist and Assistant Superintendent, Washington Filtration Plant, Washington, D. C.

do this? The epidemic described in this paper was severe enough to thoroughly frighten the people of Watertown, frighten them into far greater precautions against infection by typhoid from all sources than they would have used except under the influence of such a fearful calamity. And it is logical enough to believe that these precautions that individuals took of their own free will had a very appreciable effect in preventing many cases that would otherwise have been contracted. This is not a new idea, nor is it hard to find evidence tending to support it. For instance, take the typhoid record Dr. Soper has presented for Watertown, supplementing it with the rates for the three years that have passed since the epidemic year, as shown in Fig. 13.

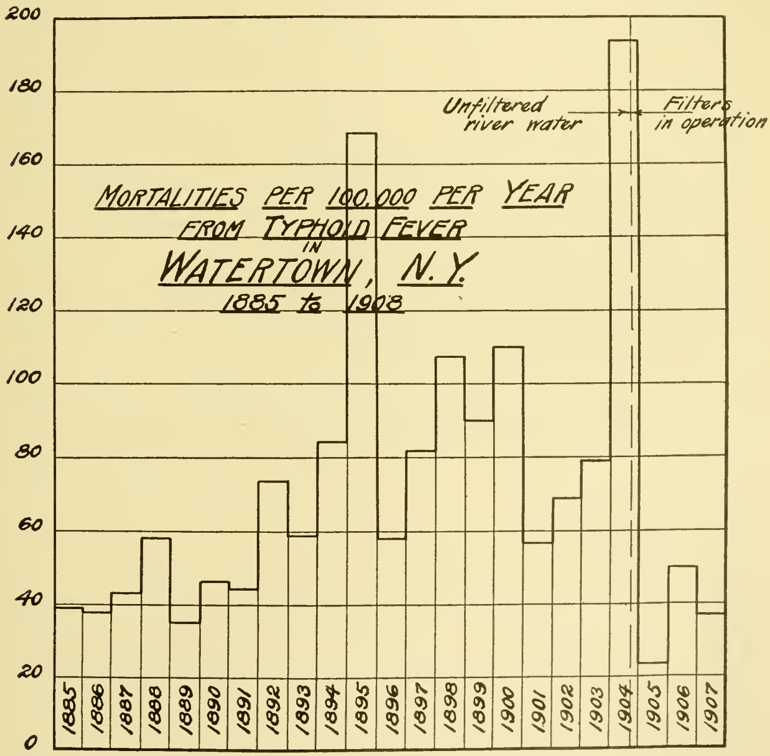


FIG. 13.

Dr. Soper speaks of the epidemics in 1895. They are very evident on this curve. Vigorous preventive measures were applied, largely through individuals. The result was that the curve for the following year dropped very low for Watertown. But it did not stay low. With the sense of security that came with the low rate of 1896, the individual seemed less impressed with the necessity for the vigorous precautions of the year before, and consequently we see the typhoid rate climbing up again.

No distinct epidemic has been noted for the years 1898–1900, but the conditions are plain, with an average typhoid death-rate for the three years in excess of 100 per 100 000. No doubt this caused a campaign, following the high rate of 1900, against the infection, with the result of bringing the rate down in 1901 to 57 per 100 000. Then again the curve rises for several years until it culminates in the epidemic which forms the subject of this paper.

In the year following the epidemic year the typhoid death-rate dropped, as is shown, to 24 per 100 000, which is lower than it had been in more than twenty years for which records are available, and considerably less than one half the low rates reached in 1896 and 1901. A mass of most conclusive evidence points to the improvement in the water supply as the large factor in this reduction of the death-rate; but is it not very probable that the preventive measures prosecuted so vigorously the year before had a decided influence in reducing that portion of the typhoid that was not affected by the improvement in the water supply? And is this not borne out by the fact that the rate jumped up again the two succeeding years, indicating as before the wearing off of the educational effects of the epidemic year in the security apparent in the minds of the public from the improved conditions and the lowered death-rates?

The curve of typhoid fever death-rates for Washington, D. C., has during the past twenty-five years shown variations of this same nature that were not explainable by any known changes in the quality of the water, and for which the ideas suggested above do seem to afford a reasonable explanation. The curves for many other cities, too, show similar variations.

There are many factors, such as meteorological, climatic, and racial conditions, as well as the questions of pure water and proper

drainage, that influence typhoid rates in ways that are too devious to follow, and there is no intention of arguing the elimination of such considerations nor of pretending to dismiss with one simple argument a question which is of the most serious complexity. This discussion is presented simply with the idea of bringing out the importance of two points: First, the educational effect upon a community of a distinctly epidemic typhoid condition, with all the object lessons attendant thereon; and second, the error that has been so commonly made in placing the entire blame for high typhoid rates upon the water supply, even when that is known to be badly polluted. It is evident enough that the degree to which the water supply alone may be blamed varies with the amount of pollution; but even assuming this to be a very considerable degree, the other causes tending to produce typhoid are generally not insignificant, and they should not be overlooked, as has so often been done.

A great deal has been said upon the subject of typhoid fever in Washington since the installation of the filtration plant nearly three years ago. This city had long been afflicted with a high typhoid rate, and the water supply, drawn from the Potomac, had been blamed for it. Naturally all agreed in predicting a great reduction in the typhoid with the use of the purer water supply. And naturally all were disappointed and mystified upon seeing the typhoid appear with no diminution in quantity or intensity during the first year of operation of the filters. This had the effect of bringing down much unfortunate and sensational criticism of the water supply, and the new filters were advertised far and wide as a failure.

The results of the studies on the quality of the water, both before and after filtration, the results of investigations that have been carried on for two years by the Public Health and Marine-Hospital Service, the close consideration of the problem by the health department of the District of Columbia, the deliberations of the Medical Society of the District, and the opinions quite unanimously formed by the many sanitarians and experts who have given this subject their consideration, all point to the conclusion that the early assumptions were wrong. The filters were not a failure, but were doing most excellent work. The advent of

filtered water did not cause a marked and prompt reduction in typhoid because the Potomac water was not a large factor in the causation of the disease. The importance of certain other factors, which had before been neglected in favor of the polluted water theory, was accepted and emphasized.

When, years ago, the relation was pointed out between polluted water supplies and typhoid fever, and emphasized by epidemic after epidemic of the most virulent nature, with the most convincing evidence to prove this relation, the dangers lurking in polluted water were preached far and wide; and in the light of the evidence adduced, the theory of water-borne typhoid was almost universally accepted.

This was right and proper. The facts in a great many spectacular outbreaks of typhoid fever have been so closely in accordance with this theory as to eliminate every doubt of its application to the cases in question. There is an element of danger, however, in the too complete acceptance of this theory. There is danger of forgetting almost entirely that the disease may have its origin in many other causes. In their highly commendable enthusiasm over the application of this theory, some of the ablest writers in the country on sanitary subjects have entirely ignored this possibility. And therefore it is that the writer wishes to comment in this way upon the too complete acceptance of the water-borne typhoid theory to the exclusion of other factors, the importance of which has been underestimated. Engineers know without question how to eliminate the typhoid that is carried through water supplies; and there the function of the engineer ceases, or rather merges in with that of the municipal official upon whom falls the burden of dealing with that part of the typhoid which has been called "residual." The indications seem to be that in some communities this "residual" typhoid may be a large part of the whole, and the need of greater knowledge in regard to it is evident. In connection with some problems it has been thoroughly studied with promising results in some directions, though less so in others, but it should be persisted in without discouragement.

The importance of education in this subject of typhoid has been mentioned. An epidemic is a good means to that end, but it is an expensive and heart-rending, as well as an impressive ex-

perience. Education through the medical fraternity seems logical for this subject, but it has been found unsatisfactory and ineffective. The same is true of bulletins, circulars, and newspaper publicity. But could any means be found more satisfactory than through the public schools? For the subjects of study of the school children, if of human interest, very quickly become the subjects of discussion and perhaps of further study in the home. They need not be techanical; the less technical, in fact, the better. There are a few admirable books that would answer the purpose, and the writing of others awaits only the creation of the proper demand.

The writer is inclined to offer an apology for dwelling upon topics that lie more strictly within the realm of education and of medicine, but while they are of little value to a superintendent in checking waste, or to an engineer in the selection of pumps, they are pertinent in the discussion of a subject which concerns us all, as this does.

One other point the writer wishes to refer to is a case of gross carelessness in the pumping station at Watertown. The regular intake extends, as Dr. Soper has stated, to a settling basin. During the construction of the filters and the extension of the intake to the new plant and coagulating basin the city supply was drawn partly through an emergency supply pipe directly from the flume along the east side of the building. About 50 or 60 feet above this emergency intake, and situated within the pump-house, was the toilet-room jutting out over the flume, a splendid opportunity for another spectacular outbreak of typhoid by a very direct transmission of infectious material, only wanting the proper individual, and disgusting from its evident proximity. Inquiry failed to reveal any one who had suffered from the fever, and who had worked in, or frequented the pump-house. The danger from this source was eliminated, of course, when the proper intake to the new filters was put in service, and later the toilet-room itself was removed. But it is an example of the dangers that may lurk right under the official eye and escape detection in the general search that is made for sources of pollution.

Dr. Leonard P. Kinnicutt * (*by letter*). No one can read Dr. Soper's most interesting and instructive paper on the 1904 typhoid

* Professor of Chemistry, Worcester Polytechnic Institute, Worcester, Mass.

epidemic at Watertown, N. Y., without feeling how great are the strides made by epidemiology during the past two years, and how differently a typhoid fever epidemic is handled to-day than it would have been yesterday.

Yesterday we sought for the primary cause and, finding it, we contented ourselves with an attempt to prevent further spread of the disease from the original source, leaving almost untouched all secondary causes. To-day it is considered that unless all possible means are used to prevent the indirect spread of the disease, comparatively little has been done.

Koch's investigations at Triers showed that for the prevention of the spread of typhoid fever almost as great precaution must be taken as is the case with scarlet fever or diphtheria; and possibly the most interesting part of Dr. Soper's paper is the description of what might almost be called the extreme measures that were used at Watertown to prevent all possible sources of danger of the infection being carried from person to person; and to those familiar with city governments it shows what "courage of conviction" is able to accomplish; and there is no question that the work of Dr. Soper will be of great use and make the work of the epidemiologist in the future much easier in persuading city officials that only by the most thorough measures can an epidemic of typhoid fever be stamped out.

Possibly one point in Dr. Soper's paper that is not sufficiently dwelt upon is regarding the closing of all suspicious wells. This, of course, may have been done at Watertown, though the statement that the result of the examinations of the wells showed that the water of most of them was of an unsatisfactory quality, yet only in a few cases were the wells ordered closed, leaves the question somewhat in doubt. In times of epidemics it would certainly be best to close all wells which gave any indication of pollution.

Dr. Soper, in speaking of the mechanical filtration plant which was in course of construction at the time of the epidemic, gives the typhoid fever rate since it was put in operation, in 1905, 24 per 100 000; in 1906, 50; and in 1907, 37; but makes no comment on these figures. Professor Sedgwick, in referring to them and to the continued typhoid at Washington since the slow sand filters were put in commission, states that in his belief it is due to residual

typhoid or to typhoid due to other causes than the public water supply. Not questioning at all the fact that typhoid is due to other causes than polluted water, is it not possible that the prejudice of the French sanitarians against filtered water and the present tend in Germany to the development of ground waters as a source of supply is not without justification?

Dr. M. J. Rosenau * (*by letter*). In addition to the many excellent features of Mr. Soper's report, one is especially impressed with the fact that Watertown got off very cheaply. The efficient and energetic measures adopted to suppress the epidemic were put into effect at a small cost, compared with the price of life and health. Watertown owes to the sanitarian a debt of gratitude. Ordinarily it takes a catastrophe to stimulate a community to adopt vigorous sanitary measures. It is a matter of much regret that cities suffering with residual typhoid, or with typhoid in what might be called the *status epidemicus* cannot be stimulated to adopt vigorous suppressive measures.

Dr. Soper. Among the many interesting questions raised in the discussion of this paper, there is one upon which there is substantial agreement. All agree that typhoid must be regarded as not merely an infectious disease, but as one that is contagious as well. The fact that a public water supply must not be alone held responsible for cases of sickness in an epidemic like that at Watertown is recognized by all. The general acceptance of this view is peculiarly agreeable to me since, as Professor Sedgwick says, my convictions with respect to this point have strongly influenced my work for the last five years. That the plan for the Watertown campaign has met with approval at the hands of the very experts whose opinions I most value is very gratifying.

There never was any doubt in my mind as to the effectiveness of the work. To stop the epidemic a sum approximating $25 000 was spent in two months. The epidemic had been running without abatement for two months. Within two weeks after the measures of suppression were put in force, the number of new cases each day diminished to about one half, and although the epidemic continued for nearly two months longer, its intensity never again increased, but diminished steadily to the end. If the table given in the body

* Public Health and Marine-Hospital Service, Washington, D. C.

of the paper showing the number of cases reported daily does not indicate the effectiveness of the suppressive measures, I am at a loss to comprehend to what cause the diminution is to be attributed.

The only regret is, as Mr. Baker has pointed out, that the work of stamping out this epidemic was not begun earlier; that it was not, in fact, made unnecessary by preventive and remedial sanitary measures applied to the water supply years before. Health Officer Willard in his discussion has explained why some valuable time was lost. Acting on advice which I myself had given in a paper read before the assembled health officers of New York state some months previously, the city of Watertown applied to the New York State Department of Health before seeking help from outside sources. Had the state responded to the call with the promptness and thoroughness which the situation demanded there is no reason why the city should not have had relief three weeks earlier. The delay in calling upon the State Department and the indifference with which the citizens had continued to drink polluted water from the Black River for so many years prior to the epidemic can only be attributed to apathy, an apathy which, as has been pointed out by Mr. Whipple, is not peculiar to Watertown. Apathy toward typhoid exists everywhere in the United States.

The personal element enters into the cause of typhoid fever to a far greater extent than is commonly understood, for typhoid is transmitted from one person to another not only in epidemics, but at all times. The cause of this personal transmission is due, in the last analysis, to individual ignorance and indifference.

The time has passed when a single channel of transmission like a public water supply should be held accountable for all the cases of typhoid which occur in an outbreak. The possibilities of transmission from persons who are sick and from healthy bacillus producers are sufficient to account for many cases in every epidemic. I believe that practically all sporadic or prosodemic typhoid is produced in this way. Only by preventing typhoid from spreading in this way can we hope to eliminate it utterly. As Professor Sedgwick says, typhoid is commonly looked upon as infectious and not contagious. It is too often regarded as transmissible in only one way in an epidemic, as by water, for example. This is a mistake.

A point to which Professor Kinnicutt has alluded, and which

was apparently not made sufficiently clear in my paper, is the danger which is to be apprehended from local foci other than strictly personal ones. Wells belong to this class. There is no doubt in my mind that in typhoid epidemics, wells which are ordinarily only polluted sometimes become infected with typhoid germs and give rise to cases of typhoid which are attributed to the main source of infection. I found in the epidemic at Ithaca a well of this kind. The well had long been regarded as pure, and when the public learned that the city water supply was dangerous, as many people as possible turned with confidence to the well for their drinking water. So great was this confidence, and so large the demand on the well, that the water was piped from the private property upon which the well was located to another house in the vicinity. At first no trouble resulted. But toward the end of the epidemic a case of typhoid occurred in the house where the well was located. The attending physician did not recognize the sickness as typhoid, and the dejections were allowed to pass without disinfection through the sewer. The sewer was defective and the bacilli entered the well, producing fifty cases of typhoid with five deaths.*

The danger from wells was constantly guarded against at Watertown. Wells located on private property and in mills were examined with much care by means of analyses and inspections. One of the objects of the laboratory was to examine the waters of the wells. At Ithaca 946 private wells had been examined under my direction, and at Watertown, although there were fewer wells, the work was no less thorough. The people were warned against the use of wells whose purity rested merely on common repute. It was generally necessary to present convincing evidence of danger in order to prove that the well was polluted, for people in small cities are as loyal to their wells and privies as though they were members of the family. But once the danger was made plain, a family would willingly abandon its well. Few wells were formally ordered closed for this reason. The object of the spring water supply distributed by the Board of Health was to cut off the need of using the public water and the private wells as far as practicable.

* "The Epidemic of Typhoid Fever at Ithaca, N. Y.," by George A. Soper, Ph.D., Journal of New England Water Works Association, Vol. XVIII, No. 4, pp. 445–446.

I feared contamination of the milk supplies, for it is not uncommon in an epidemic like that at Watertown for country people who are attacked during temporary residence in the city to go back home to be nursed through typhoid. One case of typhoid in a dairy might very possibly cause many others. Here was a danger which it is extremely difficult for a city like Watertown, when afflicted by epidemic, to guard against. The farms which supply the milk are likely to be miserably dirty. To at once raise them from their filthy state to such a condition of sanitary excellence as to exclude the danger that the milk may become infested with typhoid germs is impossible. I am confident that in some of the long and intense typhoid epidemics which have afflicted American cities, milk supplies have become foci of typhoid germs long after the original cause of the epidemic has ceased to act. At Watertown the Board of Health sought to combat this danger by warning the public against drinking raw milk and by exercising such supervision as was practicable over the sources of the milk. It is proper to say that these precautions were not as thorough as was desirable, but no milk supply was found to be contaminated.

Along with such foci as water and milk belong dangers incident to the consumption of fruit and other food which are handled and exposed for sale within an infected city. At Watertown an Italian fruit dealer who was found to be harboring a case of typhoid in his establishment was given the choice of closing his shop or having the patient removed to hospital.

Mr. Whipple has said that the original source of the infectious matter seemed to be less effectively guarded against than the local sources. This criticism is, in a measure, just. The public water supply was, in my judgment, so heavily polluted that no measures intended to exclude or remove the polluting matters would be at all likely to prove successful. It seemed to be a sheer waste of time and money to attempt to " clean up " the drainage area, as is so often attempted in epidemics. Two months of spring weather probably had done much more than human effort could do to remove all the defilement which it was practicable to remove.

On this point there was, as pointed out in the paper, a clear division of opinion between the state department of health on the one hand and the city department of health on the other. It

was not doubted by either that the typhoid epidemic had been brought upon the city by the water and that permanent sources of pollution still existed upon the river. But it seemed to me impracticable to do away with these sources. Because of the great expense involved it had been impossible for the water board to avoid them by enforcing the state law. The drainage area was extensive and at several places villages and mills crowded the river banks, and even islands in the river were built upon. Several sewerage systems were discharging into the stream when the epidemic broke out. These sewerage systems could not be eliminated. So far as typhoid was concerned, it was necessary first to find the infectious matter before it could be removed. The investigators available for this undertaking were such young men as happened to be out of employment and could be induced to take up this work. They knew nothing of sanitation. The inhabitants of the drainage area were by no means all on friendly terms with the city and it seemed undesirable to earn their hostility by a clumsy interference with what they had long considered were their rights. The details of the procedures which should be followed in the event of a case of typhoid being discovered were by no means well defined. Obviously they should vary with circumstances. The best that could be done would be to trust to the judgment of the inspectors. In view of the fact that the city had its hands full in guarding against local sources of infection, it seemed far better to leave the cleaning of the drainage area to the state department of health, place emphasis upon the fact that the river water was dangerous and must remain so, and at the same time place within the reach of all an abundant source of water of unquestioned purity.

At the same time, by special arrangement with the authorities at Deferiets, a number of cases of typhoid in that village were taken off the sewerage system and provision was made for disinfecting and disposing of the excreta in a sanitary manner. The hospital facilities at Watertown were extended, as always, to the country people. The laboratory facilities of the Watertown Board of Health were placed at the disposal of all physicians on the drainage area for the discovery of typhoid cases and of people who were not sick but who were unconsciously producing typhoid

bacilli. In this way a little boy was discovered who had recovered from typhoid and who was being sent to school in one of the villages on the river above Watertown with urine literally clouded with typhoid bacilli.

With so many possible sources of typhoid within and near the city, it is not strange that the epidemic, once started, should have been of long duration. In fact, it is not clear why typhoid should ever be completely stamped out without careful, skillful, and long-continued effort. In some epidemics it seems not to stop until every susceptible person is attacked.

The danger of an indefinite continuance of typhoid seems the greater when we consider the part played by healthy bacillus carriers in the dissemination of the disease. In the case of a chronic bacillus carrier whom I happened to discover in 1906, seven separate household epidemics were produced over a period of five years, a record which probably would be increasing to-day were it not that the unfortunate person who was producing the germs was taken into custody by the New York City Department of Health and detained as a menace to the public health.* In numerous occurrences of typhoid in Germany, and in a notable outbreak just reported by Dr. R. M. Buchanan, of Glasgow, the danger of unsuspected typhoid bacillus carriers in dairies, and wherever food is handled, has abundantly been set forth.

The bearing of all these facts upon typhoid is evident. Residual typhoid no longer necessarily means, as we all understood the term to mean when Professors Sedgwick and Winslow originally proposed it, the typhoid which remains in a city after the public water supply has been perfected. It may mean the typhoid which remains when the sources which lie within the city have been satisfactorily eradicated and only the water supply remains open to suspicion. In many instances these proximate sources may alone be to blame. The experience of Washington, and the thoughtful remarks of Mr. Longley in connection with this subject, well illustrate the necessity of taking advanced ground in accounting for the presence of typhoid fever everywhere.

As Professor Kinnicutt has said, great progress has recently

* "The Work of a Chronic Typhoid Germ Distributer," by George A. Soper, Ph.D., *Journal of the American Medical Association*, June 15, 1907.

been made in our understanding of the cause of typhoid, and the opinions of yesterday are no longer those of to-day. But there still remain some obscure problems connected with this subject. I agree with Professor Winslow in believing that we are only at the beginning of our knowledge of typhoid, and I cannot share Mr. Whipple's view that the ways in which the typhoid germ is transmitted and the ways of preventing this transmission are all well understood. I hope the knowledge of to-morrow will be considerably in advance of the knowledge of to-day.

Mr. Allen has raised an interesting question. He has called attention to the fact that typhoid epidemics are sometimes highly educational, and he and Mr. Longley have remarked that the sanitary instruction, coupled with the alarm which people experience at such times, apparently cause them to exercise precautions that, for a few years at least, after the epidemic, protect them to a considerable extent against typhoid. With this view I am in general agreement. But I cannot think that greater precautions alone account for the fact that in the year or two following an epidemic there is likely to be much less typhoid than previously existed. I think other forces are at work also.

Why Watertown has had so much typhoid since its epidemic of 1904, I am unable to explain. Mr. Jennings suggests that it is because the country people in the vicinity use the city hospitals, and Mr. Whipple gives a number of reasons for thinking that the filter plant is not to blame. On the other hand, Professor Kinnicutt plainly intimates that he is not perfectly assured of the infallibility of filters. Mr. Longley apparently thinks the disease is being spread through lax sanitary precautions. This point is an extremely interesting and important one, but I confess I know nothing whatever about the persistence of typhoid in Watertown since the epidemic. I agree in thinking this question should be cleared up.

An obscure point in the epidemiology of typhoid is the fact that strangers are more likely to be attacked on visiting a typhoid city than are the customary residents. At Ithaca typhoid was prevalent for years among new students at Cornell University. So disproportionately large was the number of freshmen attacked that the disease which filled the infirmary every fall was called

"freshman fever." Troops sent to a distance are said to be much more liable to typhoid soon after reaching their destination than subsequently. Similarly, typhoid epidemics appear to be most intense in places where the people have previously suffered least from that disease. It is possible that the epidemic at Watertown would have claimed more victims at the outset had the water supply not been so contaminated and typhoid so common in other years. Does continued exposure to the germs always either produce typhoid fever or confer immunity? There is here a most interesting field for research.

It is difficult to account for the obscure question of the seasonal distribution of typhoid to which Professor Winslow refers. Excluding epidemics due to surface water supplies, typhoid is, in northern countries, chiefly a disease of autumn. I believe that people are more exposed to typhoid germs at this season than at any other. At this time people are moving about the country more freely than at other seasons, exposing themselves and others to an unusual extent. Probably people are more susceptible to typhoid in the autumn. This may be because of changes in diet, or it may be because of certain unusual metabolic conditions due to changes in temperature. Certainly personal susceptibility changes from day to day and it probably varies from season to season.

Is it not possible that the difference in seasonal incidence of typhoid among Indian and British troops mentioned by Professor Winslow may be due to some difference in personal habits? I cannot think that the temperature of the summer or early autumn has any material effect upon the vitality or virulence of the typhoid organism outside of the body, or that the weather directly affects one class of men in one way and another in an opposite way. I am inclined to believe that the causes which lead to the prevalence of typhoid in the autumn are due to (1) greater personal susceptibility; (2) greater exposure to the germs.

Before attempting to explain what appears to be the excessive prevalence of typhoid in some American states as compared with others, I should like better assurance of the correctness of the statistics. It is a cause of just reproach that vital statistics are so inaccurate in America. Even the statistics of deaths are unreliable in our most enlightened states, and this being so, what

reliance can we place upon the reports for the whole country? In the masterly investigations made into the causes of typhoid fever among the American troops in the Spanish War, Drs. Reed, Vaughan, and Shakespeare considered that not over 50 per cent. of the typhoid cases were discovered by the average civilian physician. This is not denying, however, that typhoid is more prevalent in warm countries than in northern ones. There is much evidence to support the interesting point raised by Professor Winslow.

Mr. Allen and Mr. Longley, Mr. Whipple and Mr. Baker, have urged the necessity of official action in respect to the control of typhoid fever, and the suggestions which these gentlemen make are worthy of most careful consideration. There is need of defining city and state limits of supervision over the pollution of streams; there is need of really useful state rules for the protection of surface water supplies; water boards should insist that boards of health trace typhoid cases to their sources. Physicians should report their cases of typhoid. It is high time that the principles of sanitary science applicable to the prevention of typhoid were recognized by educational authorities and taught more rationally and effectively in the schools.

As Professor Sedgwick has eloquently and forcibly pointed out, the keynote to better work in the prevention of typhoid lies in adopting higher standards of living. Higher standards should be established in every branch and department of public health work, including the conduct of public water supplies. The adoption of higher standards can alone eliminate typhoid.

Typhoid will continue to be prevalent so long as indifference toward it continues. The tribute which the American people are paying for this indifference is the loss of not less than 20 000 lives, $150 000 000, and the heart-rending miseries which are entailed by over 300 000 cases of typhoid annually.

THE TROY WATER WORKS EXTENSION.

BY E. L. GRIMES, CITY ENGINEER, TROY, N. Y.

[*Read March 11, 1908.*]

HISTORICAL.

The city of Troy is located on the easterly bank of the Hudson River, at the head of navigation. It occupies the river plain for a distance of about six miles north and south and extends back upon the hills to the eastward from one to two miles. The river plain has a general elevation of about 30 feet, while the hills occupied on the east rise to elevations of from 300 to 500 feet above tide-water. At the time the water works system was first undertaken, the city had a population of about 12 000; it now has a population of about 77 000.

The Troy Water Works Company, a private concern, was incorporated by act of the Legislature, April 18, 1829. This company intended to supply water for domestic purposes only and seems to have accomplished very little.

About a year after the company above referred to was incorporated, the Common Council of the city passed a resolution creating a committee with instructions to make surveys, plans, and estimates for bringing " a suitable supply of good water " into the city. On August 11, 1830, this committee reported upon two plans, — one to take water from the " Gorton Springs," at an estimated cost of $60 000; the other to use the " Piscawen Waters," at an estimated cost of $80 000.

In May of the following year a committee was appointed to see what arrangements could be made with the Troy Water Works Company to supply the city with water for extinguishing fires, watering streets, etc., and to learn upon what conditions the company would transfer its charter rights to the city, provided the necessary legislation could be obtained. The committee reported, March 26, 1832, that they could not make satisfactory arrangements with the Troy Water Works Company for the supply required,

but that the company had agreed to surrender its charter to the city upon the payment of the amount actually paid out by them, $174.34. The committee further reported that the legislature had already passed the necessary bill for the transfer, by an act entitled," An Act in Relation to the Troy Water Works Company and for insuring the City of Troy a Supply of Water for the Extinguishment of Fires and for Other Purposes."

Acting upon this report, the Common Council ordered a house-to-house canvass to be made to ascertain the sentiment of the people in regard to the matter. As a result of this canvass, it was found that 637 were in favor, 8 opposed, and 18 indifferent to the project. One hundred and seventy-eight agreed to take water when it was brought into the city.

Surveys for the construction of the reservoirs upon the Piscawankill were begun in March, 1833, and contracts for the work were immediately made. A contract was also made with Samuel Richards, of Philadelphia, to furnish cast-iron pipe and castings at the following rates delivered in Troy: 12-inch, $1.85 per foot; 10-inch, $1.50; 8-inch, $1.30; 6-inch, $0.90; 4-inch, $0.50; 3-inch, $0.40 per linear foot, and branches and other castings, $62.50 per ton.

The works were completed in 1834 and consisted of a diverting dam across the Piscawankill; two open and one covered reservoirs, having a combined capacity of about 1 000 000 gallons, and a 12-inch main leading from the covered reservoir to the city. The ruins of these old reservoirs are still to be seen just easterly of the Boston & Maine Railroad near Eddy's Lane.

The work had been completed but two years when it became evident that some means should be devised to increase the supply. In 1839 land was purchased and a dam known as the Fire Dam was built for the purpose of storage upon the site now occupied by the low-service distributing reservoir. This reservoir appears to have been insufficient, for the next year the committee in charge suggested pumping water from the Hudson River.

The idea of pumping seems to have been abandoned for some reason, and in the fall of 1840 the right was obtained to erect and maintain a dam at the site now occupied by the dam of the Brunswick reservoir for the term of two years, with the privilege of

buying the property outright at the end of that period if the city elected to maintain a permanent reservoir at that point. The dam was built and all the property rights were later acquired.

The full development of the Piscawankill watershed as a water supply was finally accomplished by building the present "Upper Oakwood" reservoir in 1859–1860, the "Lower Oakwood" in 1861–1862, and the "Vanderheyden" reservoir in 1868. These reservoirs, together with the "Brunswick," gave a total available storage capacity of about 281 000 000 gallons.

In 1872, Wm. J. McAlpine, civil engineer, who was employed to examine all the feasible sources of water supply for the city of Troy, and report on the cost of procuring the same, made a report in which he suggested five sources of supply, namely, the Tomhannock, the Poestenkill, the Hudson River, the Deepkill, and the Wynantskill. In concluding his report, he says: "The Tomhannock plan possesses advantages over all of the others in the economy of its cost and the purity of its water, and is equal to any of the others in the abundance of water." None of the schemes suggested by Mr. McAlpine was carried out.

In 1877 and 1878, Prof. D. M. Greene, civil engineer, presented reports and plans for pumping water from the Hudson River, and in 1879 a pumping plant was built under his direction. This plant consisted of two Holly duplex pumps, each of 6 000 000 gallons daily capacity, together with the necessary intake crib in the river, a tunnel to convey the water from the intake to the suction well, and a 30-inch cast-iron force main extending from the pumping plant to the "Lower Oakwood" reservoir, a distance of about three miles.

The water was pumped from the river into the "Lower Oakwood" and allowed to flow by gravity from there to the distributing reservoir.

The low-service distributing reservoir was built in its present form in 1883, at which time a 24-inch supply main was laid from it to connect with the distributing system of the city. This line of main pipe crossed the stone arch just below the reservoir and connected with the 20-inch main of the old system near the old covered reservoir. Provision was also made at the new distributing reservoir for another 24-inch main. This was laid down

Eddy's Lane, or Glen Avenue, and Seventh Avenue to Park Street, connecting with the distributing system, in 1885.

The middle service system was connected with the "Upper Oakwood" Reservoir in 1879, and the high-service system was taken from a small new reservoir, known as the High Service Distributing Reservoir, built especially for that purpose during the same year.

The supply thus provided proved to be adequate until about 1893, when Prof. W. G. Raymond and Elnathan Sweet were employed to investigate and report upon a new source of supply. These engineers made a report upon the development of the Poestenkill and Quackenkill, two streams lying to the southeast of the city. Nothing further seems to have been done toward procuring an additional supply until 1900. In the meantime Professor Raymond's attention was directed to the Tomhannock Creek, a stream of considerable size flowing through the towns of Pittstown and Schaghticoke into the Hoosick River. He found upon investigation that a very large storage reservoir could be made there at comparatively small expense.

The Tomhannock Reservoir would not, however, be at a sufficient elevation to supply more than the low, middle and Lansingburgh services. Therefore it was finally decided to develop the Tomhannock for these services, and the Quackenkill for the high-service supply.

Authority to expend $1 250 000 for an additional water supply was obtained from the legislature in 1900, and the work was immediately undertaken under the direction of Prof. W. G. Raymond as consulting engineer.

THE QUACKENKILL.

The Quackenkill drainage area is located on the mountains east of Troy in the town of Grafton. It consists largely of grazing and wooded lands and contains several lakes of considerable size. These lakes are located in the more elevated portions of the area, are fed largely by springs, and contain water of very good quality. Streams flowing from the lakes join to form the Quackenkill. On account of its great elevation above the city it affords an excellent source from which to obtain, by gravity, an additional supply for

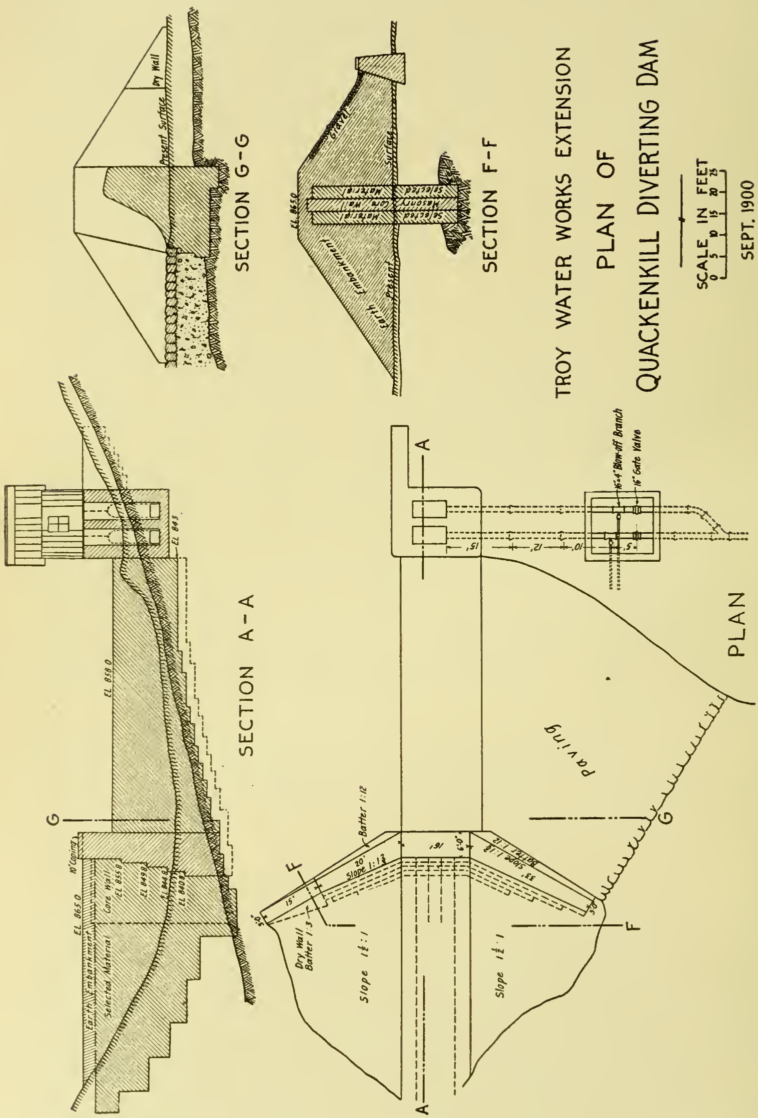

TROY WATER WORKS EXTENSION
PLAN OF
QUACKENKILL DIVERTING DAM
SCALE IN FEET
SEPT. 1900
SECTION G-G
SECTION F-F
SECTION A-A
PLAN
Dry Wall
Present Surface
Earth Embankment
Selected Material
Masonry Core Wall
Gravel
EL 865.0
EL 859.0
10' Coping
Core Wall
16"-4" Blow-off Branch
16" Gate Valve
paving
Batter 1:12
Slope 1:1¾
Slope 1½:1
Dry Wall Batter 1:3

Fig. 1.

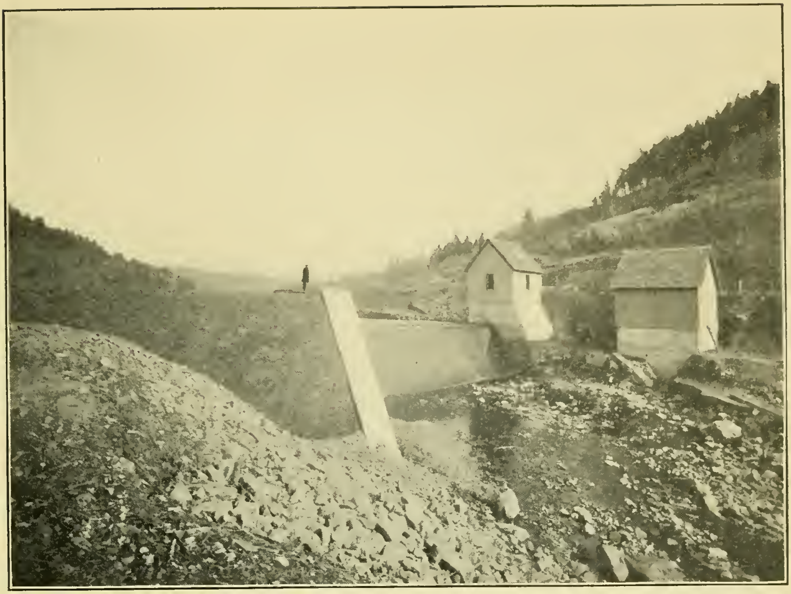


FIG. 1. Quackenkill Diverting Dam and Gate House.

FIG. 2. Tomhannock Dam Site with Culvert Completed.

the high-service system of the city. The original plans contemplated the full development of about 17½ square miles of the drainage area around the headwaters of the Quackenkill.

To accomplish this it was proposed to build dams at the outlets of the lakes so as to increase their storage capacity; two large storage reservoirs, one about 2 miles and the other about 5 miles below the lakes; a diverting dam near the town line between Grafton and Brunswick; one or more conduits from the diverting dam to the large storage reservoir, known as the "Brunswick," about 3 miles distant from the city; and a conduit from the "Vanderheyden Reservoir," to connect with the old high-service conduit at the old high-service distributing reservoir. Up to the present time the only work carried out under these plans consists of the building of the diverting dam, a single conduit from it to the storage reservoir, and a single conduit from the storage reservoir to connect with the old high-service main.

The diverting dam (Fig. 1, and Plate I, Fig. 1) consists of a concrete spillway and gate chamber, and an earth embankment with concrete core-wall. Although only one conduit has been laid from the dam to the storage reservoir, the proper connections, valves, etc., have been built into the dam for a second one, if it should ever be needed.

The conduit from the diverting dam to the "Brunswick Reservoir" consists of 29 550 feet of 16-inch, and 3 167 feet of 12-inch cast-iron pipe designed to have a carrying capacity of about 5 000 000 gallons per 24 hours. The outlet of this conduit is taken some distance into the reservoir, where it terminates in a bell-shaped concrete mouthpiece. This mouthpiece turns upward and serves to a small degree as an aërating fountain.

From the "Brunswick" the water passes over a weir or through pipes in the embankment into the "Vanderheyden Reservoir." A new intake gate-house has been constructed at the dam of this reservoir. It was built with hollow brick walls filled in solid with concrete. Vitrified paving brick were used below the high-water line, and ordinary hard burned building brick above that line. A 20-inch conduit was laid from this gate-house to a connection with the old high service conduit. This conduit is 9 000 feet in length and gives an additional static head of about 90 feet.

It also eliminates the possibilities of contamination, which so largely existed in the open channel, through which the water formerly flowed.

THE TOMHANNOCK.

The Tomhannock drainage area is located northeasterly of the city and comprises above the reservoir dam an area of 67.3 square miles. The surface is very uneven, being of a rolling or mountainous character. It is largely a farming district, only about 15 per cent. of the area being covered with forest growths. There are about 600 houses on the drainage area and a resident population of about 2 500, or 35 people per square mile.

The location selected for the reservoir is about 10 miles northeasterly of the city. Here the valley of the Tomhannock, for a distance of 5 miles, has an average fall of about 8 feet per mile and an average width of about three quarters of a mile. At the point selected for the dam, the hills on either side of the valley approach each other until only a narrow ravine lies between them.

The hills surrounding this valley are of a shale formation with only a thin covering of earth. The valley is covered with glacial drift a few feet in depth, with here and there a deposit of considerable magnitude. Bed rock is found below this glacial deposit in the upper part of the valley of the same general character as in the hills around it.

At the dam site and for a distance of three quarters of a mile upstream, where the bed rock drops off abruptly, the material underneath the glacial deposit consists of a thin layer of yellow clay overlying an extremely hard and compact blue clay and gravel, extending to a depth of more than 150 feet, as shown by borings.

The crest of the spillway dam is located at Elevation 390, Troy City datum, at which elevation the reservoir has an area of 1 685 acres. The maximum depth of water near the dam is 55 feet, and the average depth over the whole area, 22.4 feet. The total capacity of the reservoir is 12 310 000 000 gallons, 95 per cent. of which is available for use.

Of the area flooded, 250 acres were covered with woods and brush, the remainder being largely lands under cultivation. The trees and brush were all cut and removed from the area. The

farm buildings, of which there were seventeen sets, were entirely removed and the areas occupied by them carefully cleaned up; 22 000 cubic yards of muck and decaying vegetable matter were excavated and removed from the area flooded.

The question of stripping the soil from the entire area covered by the reservoir was carefully considered by the writer. The conclusion was finally reached that while stripping would be a very good thing, better and more far-reaching results could be obtained for about one half the cost by a reasonable sanitary treatment of the drainage area, and by installing a proper filtration plant.

Several highways crossed the reservoir site, and it was therefore necessary to construct about seven miles of new highways to replace those abandoned. The alignment of these roads has been made to conform in a large measure to the contour of the ground. The maximum grade allowed was 5 per cent. The subgrade was shaped so as to have a crown of 6 inches, over which was spread a gravel surfacing 9 inches in thickness at the crown and 6 inches at the shoulders, thus giving the finished surface a crown of 9 inches. The finished width of traveled way is 20 feet. The gravel surfacing was thoroughly rolled with a grooved roller and wet when found necessary to thoroughly compact it. Side gutters 2 feet in width at the bottom and 1 foot in depth extend through all excavations. A ditch was also constructed along the side hill above all excavations, with a berm of not less than 6 feet between it and the top of the slope. All embankments exposed to the wash of the reservoir are covered with riprap or stone paving. Substantial guard rails have been erected along all embankments 3 feet or more in height.

The culverts consist of 6-, 10-, 15-, and 24-inch vitrified clay pipe with concrete or cobblestone headwalls. These culverts have not been entirely satisfactory, especially in clay soil or where a small trickling stream flows all the time.

There are five bridges on the highways, with spans varying from 16 to 80 feet. The 16-foot span bridge was built with rolled I-beams. Three others were built with lattice girders, and floor systems of rolled I-beams. The fifth, an old bridge, was raised 4 feet and new abutments built under it. All abutments were built of 1 to 6 gravel concrete.

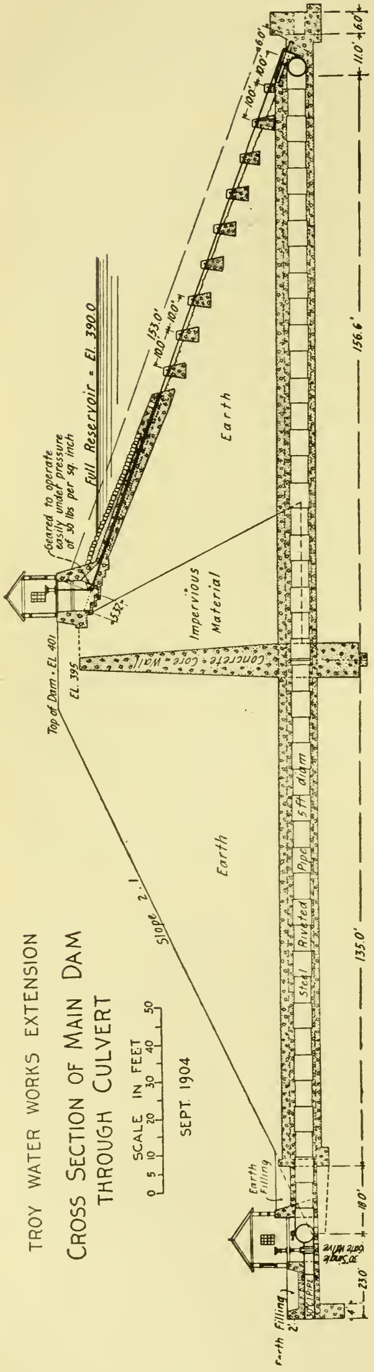


Fig. 2.

At the point selected for the dam the ravine is about 200 feet in width at the bottom and 500 feet at the top of the dam. An examination of this site had revealed the fact that it would be impracticable to reach bed-rock. Test pits dug along the proposed center line of the dam showed a depth of from 1 to 5 feet of loam and gravel, followed by a blue clay and gravel of unusual hardness and tenacity. This latter material is of great depth, as shown by the borings, and the formation was considered exceptionally good for an earth dam.

The general cross-section of the dam finally adopted, as shown in Fig. 2, has a top width of 24 feet, finished off as a highway; a back slope of 2.4 to 1; a front slope of 2 to 1; and a maximum height of about 70 feet. The back slope is paved to a point 15 feet below flow line and the remainder is covered with riprap.

The dam site was stripped of all loam and gravel down to the yellow clay. The area to be covered by the selected hard material was excavated down to and about 6 inches into the hard blue clay and gravel. There was also a cut-

off trench 4 feet in width and 2 feet in depth excavated along the toe of the up-stream slope, and another about midway between the toe and the selected hard material. The trench for the core wall was excavated to a depth of not less than 16 feet into the hard blue clay and gravel. At the westerly end, as the excavation was extended into the hill, a pocket of loose blue clay and gravel of a very porous nature was encountered, and it was found necessary to excavate to a depth of about 60 feet to procure a suitable foundation.

To provide for the flow of the stream during construction, a culvert 6 × 6½ feet, horseshoe-shaped, was built of concrete along the westerly side of the stream and the water turned into it by means of a canal and small cofferdam. It was the intention of the designer of the work to eventually close this culvert with concrete and gravel. With this in view two 36-inch sluice gates were placed at the upper end to control the flow through the culvert. These gates were of sufficient size to take the ordinary summer flow of the stream. Before the completion of the work, however, it was considered advisable to have a permanent opening through the dam at this culvert in order to unwater the reservoir should circumstances require it; a wise precaution in this particular case, as will appear later. This culvert is shown in Plate I, Fig. 2.

The plan followed for converting this culvert into a permanent opening was to build into and through it a 5-foot diameter steel riveted pipe ½ inch in thickness. At the upper end of this pipe is a T carrying three sluice gates, each having a clear opening of 1½ x 4½ feet. These gates were made narrow and long, so as to build them into and disturb the old work at the upper end of the culvert as little as possible. The gate stems were carried up the slope on bronze rollers, supported by concrete piers, to a gate-house located at the top of the dam. At the outlet end of the pipe is placed another T, carrying four 30-inch gate valves. This arrangement furnishes a means of regulating the flow through the pipe in case of accident to the sluice gates at the upper end, and of relieving the pressure upon them should it be necessary. A substantial brick gate-house is built over these gate valves.

The core wall of the dam is of concrete consisting of one part

Portland cement to five parts sand and gravel. The wall is 9 feet in thickness at the base and up to Elevation 340, from which point it batters uniformly on both sides to the top, at Elevation 395, where it is 3 feet in thickness. The concrete was deposited in 6-inch layers and thoroughly rammed. Above the surface of the ground the forms for the concrete were tied together with half inch rods. On the up-stream side a wooden washer in the shape of a truncated pyramid of four sides, about $2\frac{1}{2}$ inches in height, was placed over the rod on the inside of the form. When the forms were removed the washers were taken out, the rods cut off at the bottom of the depression, and the space filled up with rich cement mortar.

The embankments on both sides of the core wall were carried up simultaneously with the wall, but the core wall was always kept at least one foot higher than the embankments, and usually much more than that. The embankments were always kept higher at the outside edges than at the center. The material for the embankments was brought from borrow pits in dump wagons and placed one load after another the whole length of the dam. After a line of loads had been completed, a road machine was used to scrape them down to a 4-inch layer. The layer was then watered and rolled thoroughly with a grooved roller weighing 1 000 pounds per linear foot. The teams were also kept from driving in one place as much as possible and thus aided in compacting the earth. The material from the borrow pits was not uniform in character, being at one place yellow clay and sand and at another almost wholly very fine sand or coarse gravel. As the loads came to the dam they were inspected and only the best material placed on the up-stream side.

The selected hard material for that part of the embankment next to the core wall, on the up-stream side, was to have been of the hard blue clay and gravel underlying the valley. As it was found impractical to reduce it to a sufficient degree of fineness to puddle satisfactorily, a fine blue clay was substituted. This material was deposited and compacted in much the same way as the other material, except that greater care was taken with it. After the road machine had leveled off the loads and a disk harrow had been run over the material until all lumps were broken up, it

was thoroughly soaked with water and rolled. Near the core wall the lumps were broken up with mattocks and the material thoroughly compacted with hand rammers.

The embankments were carried 6 feet higher than the core wall and 11 feet higher than the crest of the spillway dam. Along the top of the embankment, on the up-stream side, a concrete curb was built, upon which was erected an iron pipe guard rail, while along the down-stream side the iron guard rail was placed on concrete blocks.

The spillway dam is located in a depression in the hills about 1 000 feet southwesterly from the main dam. It is built of concrete of the general cross-section shown in Fig. 3. The maximum depth of the cut-off wall is 25 feet below the crest. Back of this dam an 18-inch cobble paving is laid for a distance of 14 feet, with a slope of 2 feet in that distance. Beyond the paving the earth is excavated on a descending grade of 1 per cent. until it intersects the original surface.

The crest of this dam is 300 feet in length, and at each end are retaining walls rising to a height of 10 feet above the crest, to protect the earth embankment necessary to complete the dam. For a distance of 75 feet from the dam there was originally laid a vitrified brick pavement on 6 inches of gravel concrete, with a cut-off wall at the lower end. The retaining walls at each end of the dam are extended along and terminate in a twist wall at the end of the paving. From the spillway dam a canal is built around the hill at the westerly end of the main dam and enters the creek about one-half mile below. At the dam it was 300 feet in width, but narrowed down to 40 feet in going the first 800 feet. The canal was made in part by excavation and in part by building embankments. The embankments are 12 feet in width at the top and thoroughly rolled and compacted. At a point about 1 000 feet from the spillway dam the canal makes a descent of about 20 feet. To overcome the abrading action of the water at this point, two flights of stone masonry steps with retaining walls of concrete on either side were built. The upper flight consists of 7 steps of 1 foot rise each, and of width varying from 1 to 3 feet. The lower flight consists of 13 steps of 1-foot rise each and of width varying from 1 to 4 feet. Between the two flights of steps, a distance of

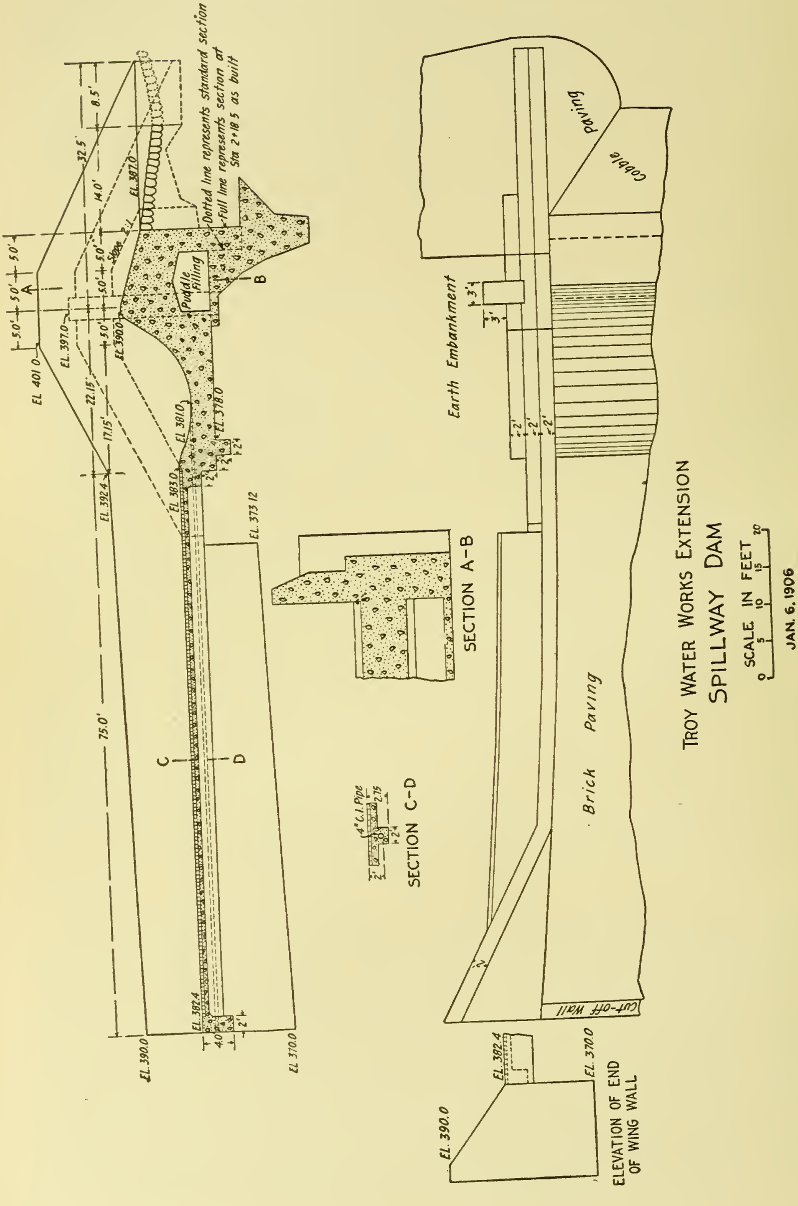

TROY WATER WORKS EXTENSION
SPILLWAY DAM
SCALE IN FEET
0 5 10 15 20
JAN. 6, 1906
Dotted line represents standard section
Full line represents section at Sta 2+18.5 as built
Puddle filling
Earth Embankment
Cobble paving
Brick Paving
Cut-off Wall
SECTION A-B
SECTION C-D
4" C.I. Pipe
ELEVATION OF END OF WING WALL
EL. 401.0
EL. 397.0
EL. 392.4
EL. 390.0
EL. 387.0
EL. 383.0
EL. 382.4
EL. 381.0
EL. 378.0
EL. 373.12
EL. 370.0
75.0'
32.5'
22.15'
17.15'
14.0'
8.5'
Slope 2:1

FIG. 3.

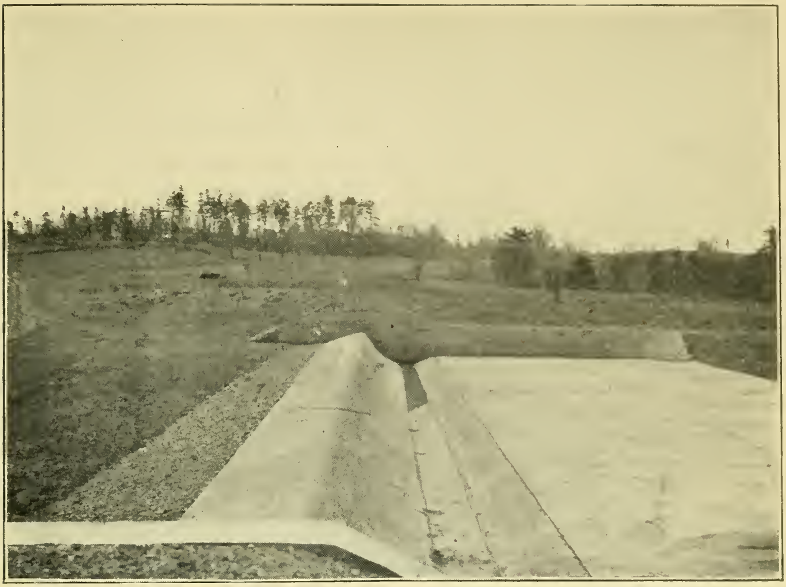


FIG. 1. Spillway Dam.

FIG. 2. Condition of Apron of Spillway Dam after the Flood of June 23, 1906.

134 feet, and for 50 feet above the upper and 50 feet below the lower steps, the bottom of the canal is paved with vitrified paving brick laid on 6 inches of gravel concrete. A view of this dam is shown in Plate II, Fig. 1.

On the afternoon of Saturday, June 23, 1906, a shower of unusual magnitude occurred on the drainage area, being especially severe in the southerly part along the Grafton Mountains. At this time the water in the reservoir had just reached the elevation of the crest of the spillway dam. The water in the reservoir had not begun to rise at 6 o'clock Saturday evening, but at 9 o'clock the next morning it had risen to a height of 14 inches above the crest of the spillway. As soon as the high stage of the water was learned, the gates of the " Permanent Opening " through the main dam were opened and the water drawn down, thus relieving the spillway of a large quantity of water, and undoubtedly preventing a great amount of damage. Measurements showed the flow into the reservoir between 6 o'clock at night and 9 o'clock the next morning to be at the rate of 2 200 cubic feet per second, equivalent to 32.7 cubic feet per second per square mile, while the maximum flow over the spillway was about 1 300 cubic feet per second. The effect of this rush of water through the spillway canal was very disastrous under the existing conditions. Before the water could be entirely diverted from the spillway, the cut-off wall and a considerable portion of the brick paving below the dam had been undermined and destroyed, the canal had been badly eroded, and the highway bridge abutments undermined, as shown in Plate II, Fig. 2.

The canal is being reconstructed and widened. The plans now being carried out contemplate the widening of the narrow part of the canal to twice its former width, and the introduction of more steps and rollways so as to eliminate the steep grades in the canal that previously existed.

The city supply is taken from the reservoir through a tunnel 5 900 feet in length, the entrance to which is located about $1\frac{1}{4}$ miles southwesterly from the main dam. The gate-house at the entrance to this tunnel contains two chambers, each having three 36-inch sluice gates arranged at different elevations, so that water can be drawn at 8 feet, 21.5 feet, and 35 feet from the surface.

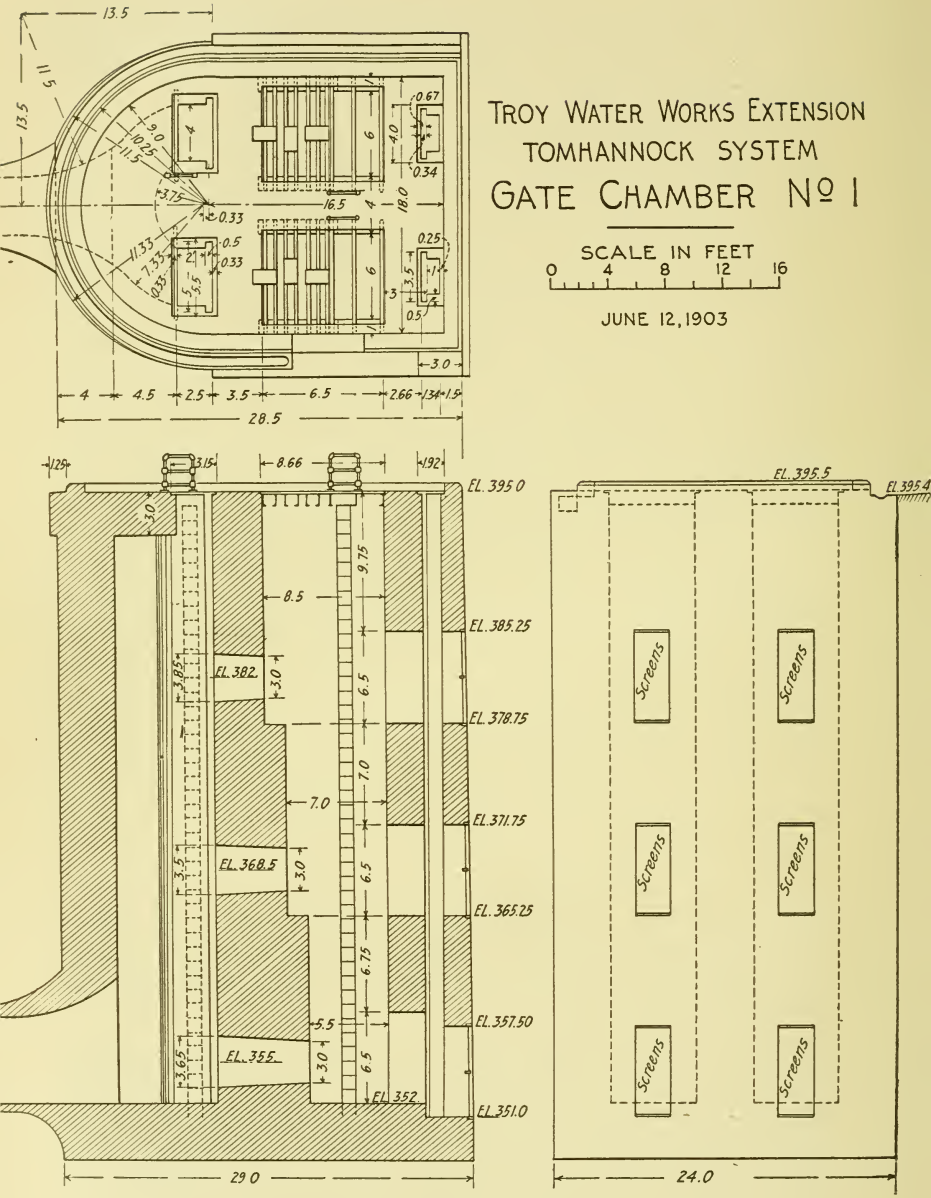
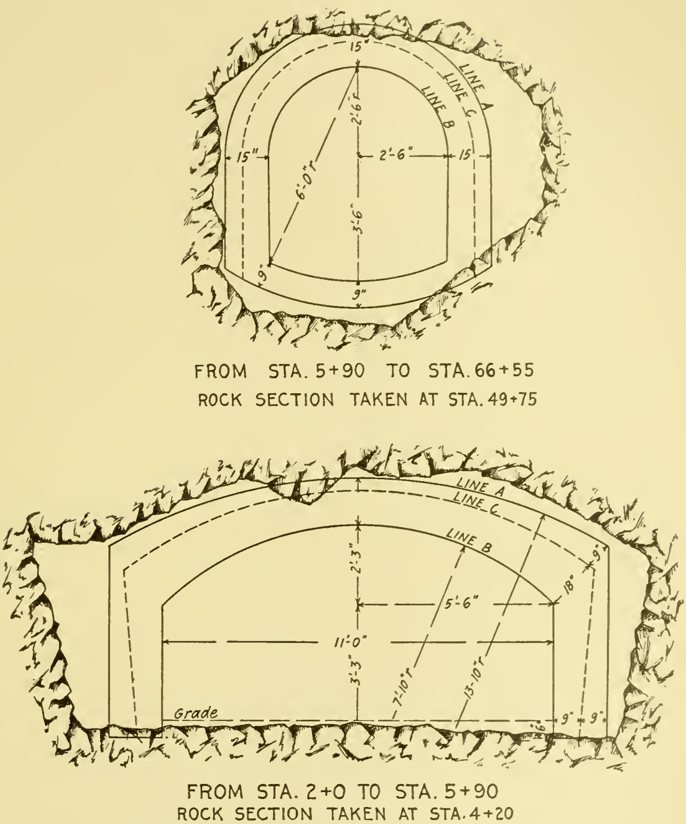

TROY WATER WORKS EXTENSION
TOMHANNOCK SYSTEM
GATE CHAMBER Nº I
SCALE IN FEET
0 4 8 12 16
JUNE 12, 1903
EL. 395.0
EL. 385.25
EL. 382
EL. 378.75
EL. 371.75
EL. 368.5
EL. 365.25
EL. 357.50
EL. 355
EL. 352
EL. 351.0
EL. 395.5
EL. 395.4
Screens
28.5
29.0
24.0

FIG. 4.

Provision is made for stop planks on each side of the gates to assist in making repairs. The openings into the gate chamber are guarded by heavy bronze screens. (See Fig. 4, and Plate III, Fig. 1.)



TROY WATER WORKS EXTENSION
TOMHANNOCK SYSTEM
STANDARD SECTIONS FOR CONCRETE LINING
SCALE IN FEET
0 1 2 3 4 5
SEP. 12, 1903

Fig. 5.

The first 5 470 feet of the tunnel was originally intended to have a cross-section of about 4 × 6 feet, and be unlined, while the remaining 430 feet was to be about 6 × 11 feet to allow of laying two conduits through it. It was afterward decided to line the tunnel with concrete. The cross-section adopted for the small tunnel has a semi-circular arched roof and is 5 × 6 feet inside measurements, and for the large tunnel 5.5 × 11 feet inside measurements, with segmental roof. (Fig. 5.) At the junction of the large and small sections of the tunnel a gate chamber is built, containing the gates which control the flow into the conduits. Access is had to the large tunnel through a well 5 feet in diameter, built at the opposite end from the gate chamber. All the structures connected with the tunnel below the surface of the ground are of concrete of the same proportions and material as used in the dam. The gate-houses above the ground are built of brick.

The tunnel extends its entire length through what is known as Hudson River shale. Near each end it appears laminated and has occasional soft seams, but as the tunnel penetrates further into it the rock becomes harder and the laminations are not so distinct. The dip of this rock is very irregular.

Excavation was carried on through four shafts and the opening at the end toward the reservoir. Steam was used for drilling during the sinking of the shafts and the driving of a few feet of the tunnel each way from them, but the greater part of the work was done with compressed air.

Only one conduit has been laid, although provision has been made in the tunnel for the second when it shall be needed. It consists of about 6⅝ miles of 33-inch riveted steel pipe, connnecting with the old 30-inch cast-iron force main at Twenty-first Street, in the former village of Lansingburgh. From this point to the lower Oakwood Reservoir the old force main was utilized. The conduit has a carrying capacity of from 15 000 000 to 18 000 000 gallons daily. Automatic air valves have been placed at all summits, and blow-offs at all low points. Manholes are provided every 500 or 600 feet in the steel conduit. It is also provided with seven gate valves placed at approximately equal intervals along the line. At five points these gate valves are placed at summits in the conduit line and, together with the air valves, are

enclosed in small brick gate-houses. At the other two points the gates are in the street and the gate chambers are entirely underground. Access is had to these gate chambers through manholes built on the side. (Fig. 6.)

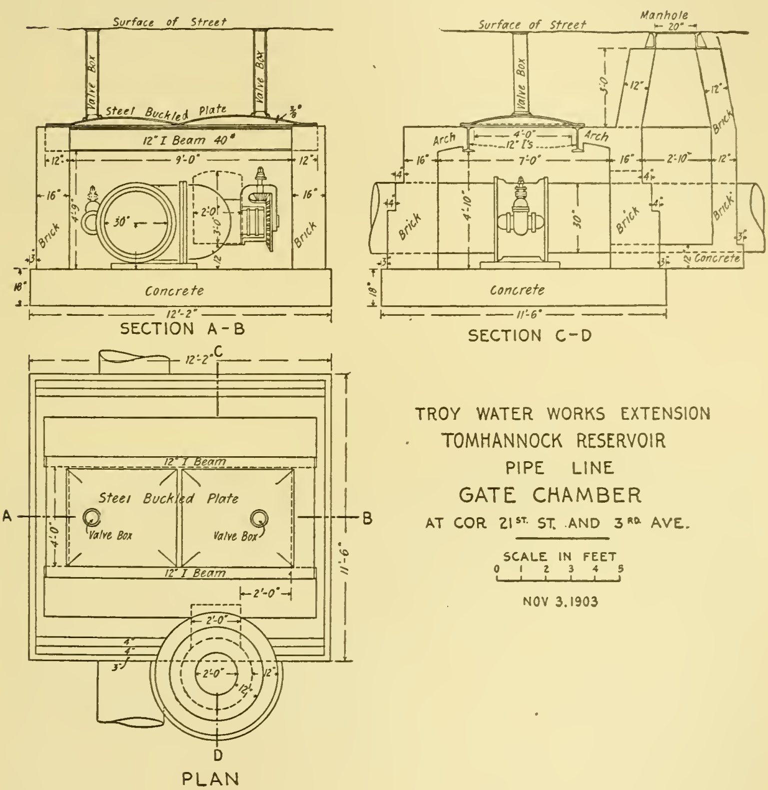


FIG. 6.

THE LANSINGBURGH SYSTEM.

The former village of Lansingburgh was annexed to the city of Troy in 1900. At that time Lansingburgh was supplied from three small reservoirs located just easterly of the village. It had also in the process of construction a masonry dam on the Deepkill and a 12-inch pipe line leading from it to the reservoir, to provide an additional supply. When the city of Troy came into possession of the work, Professor Raymond found that part of the new Deepkill dam rested upon rock foundation and part upon piles. After a careful examination of the location and conditions, he decided it would not be advisable to build the dam to its intended height, and consequently the upper 20 feet originally designed were never built.

The dam consists of a concrete core faced upon both front and back with coursed masonry. (Plate III, Fig. 2.)

What appeared to be a leakage under the dam was discovered near the center shortly after the work was completed. An attempt was made to check it by depositing clay and other materials above the dam, but this seemed to have little effect. While the quantity of water escaping was not large, a recent examination indicated some increase in volume, and that it was concentrated at a point a few feet to the right of the mud pipe near the center of the dam. The reservoir is of small capacity and only serves as a diverting reservoir.

The water-shed tributary to this system includes about 10 square miles of very hilly country lying adjacent to and westerly of the Tomhannock watershed.

QUALITY OF WATER.

The general quality of the water from all these sources is very good. During the month of January of this year, 1908, the Tomhannock water gave considerable trouble from algæ. The Quackenkill and Deepkill waters have been in use since 1902, and the Tomhannock since May of 1906. Prior to those dates most of the supply was pumped from the Hudson River into the low service reservoirs. The beneficial effect upon the health of the city of the introduction of the new supply is shown by the following table:

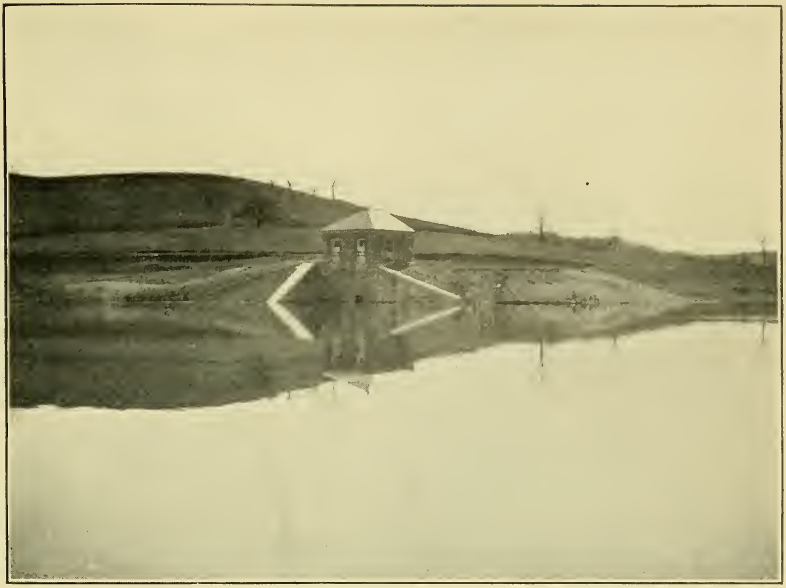


FIG. 1. Gate House at Entrance to Tunnel.

FIG. 2. Deepkill Dam and Reservoir, looking westerly.

Typhoid.				Deaths.			
Year.	Cases Reported.	Deaths.	Rate per 100 000.	Cholera Infantum.	Diarrhoea.	Diseases of Digestive Organs.	Children under 5 Years of Age.
1900	373	92	119.62	91	46	211	398
1901	176	43	55.91	56	45	178	370
1902	149	41	53.31	48	21	142	324
1903	110	23	29.91	19	10	97	315
1904	150	39	50.71	92	13	200	369
1905	160	39	50.17	70	14	184	394
1906*	91	27	35.11	24	12	113	317
1907	66	20	26.00	14	10	120	347

* Tomhannock water turned on May 21, 1906. Stopped pumping river water about May 1, 1906. Fifty cases and 15 deaths from typhoid fever reported before May 1, 1906. Average death-rate, 1901–1905, from typhoid fever, was 48.11 per 100 000. For 1906–1907 it was 30.56, or a reduction of 36½%.

COST.

The cost of construction of the different parts of the entire water works system to January 1, 1908, is as follows:

Original works and extension of Mains	$1 372 513.21
Original Lansingburgh Works	250 855.66
Deepkill System Lansingburgh Supply	150 507.67
Preliminary Investigations, Troy New Supply	25 545.18
Quackenkill System	265 916.75
Tomhannock System	1 337 138.12
Preliminary work on Filtration Plant	10 124.70
Total	$3 412 601.29

The plans for these new extensions were made under the direction of Prof. W. G. Raymond and the work was partially carried out by him. He severed his connection with the work in August, 1903, at which time the writer, who was the principal assistant engineer on the Tomhannock division, was appointed chief engineer.

POWER CAPACITY OF A RUNNING STREAM WITHOUT STORAGE.*

BY PROF. WM. G. RAYMOND, IOWA STATE UNIVERSITY, IOWA CITY, IA.

When a stream is to be developed for power, it is usual to examine such records of its flow as exist, and to take a few measurements of the minimum flow, if this is possible, as a basis on which to compute the probable minimum capacity and the probable ordinary capacity of the stream. The development is usually considered at some one point on the stream where a definite known head is available. When there are no records of the flow of the stream it is usual to examine its drainage area, compare it with that of some other stream for which there are flow records, compare also the rainfall on the two drainage areas, modify the percentage of rainfall running off from the area for which there are records, and determine the probable flow of the stream under consideration from its rainfall and these modified percentages.

While rainfall records are usually kept for each day, the published records are more commonly those of the calendar months, and this is true also of the flow records. In determining the percentages of flow on a given stream, it has been usually customary to average the flow for a number of years for each calendar month, and to compare this with the rainfall for the same calendar month for the same period. Among the streams of the eastern United States, it is found that as a general average about half of the rainfall runs off in the stream, the percentage varying in different years, according to the condition of the ground and according to the distribution of the rainfall. It is usual to say that the average conditions for power development will be shown by the average run-off or flow of the several calendar months of the year. And it is customary to determine what is called the ordinary flow,

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* This paper, originally prepared for the Iowa Engineering Society, is now submitted as a discussion to the paper on "Stream Flow Data from a Water Power Standpoint," by Charles E. Chandler, published in the December, 1907, JOURNAL.

which is variously defined by different engineers, but which is understood usually to mean that flow for which it is wise to develop the stream for power.

If the calendar months are arranged in the order of their average yield, and the yields of these months are plotted to scale, a more or less irregular curve is the result, usually showing periods of regularity of from three to five months, broken by considerable differences of flow between these more regular periods. If, now, it is proposed to develop a stream for which such a plot has been made, and it is desired to determine for a given power development what portion of the year there will be sufficient water for the operation of the complete plant, and what portion of the year there will be shortage of water, and also the aggregate shortage for the year which must be made up by steam if a plant is to run continuously, the quantity of water necessary to supply the required power with the given head is determined and marked on the diagram. All those months which fall below the line of required yield will be short of power, while those months above will furnish full power, unless there be loss of head during extreme high water. Such a diagram, or such process, purports to show the conditions that will obtain as an average for the period of years that has been considered. The minimum flow at any one time indicates the maximum amount of power to be supplied by steam, and so, on such an investigation, a plant would be designed with a full water-wheel capacity and an auxiliary steam plant equal to supplying the maximum shortage of power. In estimating the cost of operating such a plant through a period of years, the average that has been mentioned would be considered.

It is a fairly well known fact that most plants that have been developed on such an investigation as this have proved disappointing in that the amount of water power available throughout the year has almost invariably fallen short of what was promised or expected, and consequently the auxiliary steam plant has been run at greater capacity and for longer periods than was estimated in the beginning. Indeed, some plants have been designed and built with the expectation that no auxiliary steam power would be required, while the first year's operation has developed the fact that considerable additional power would be needed.

The reason for this disappointment is not difficult to determine. If the records of flow are carefully examined, it will be found that there is no year of any considerable period of years in which there is not one or more months yielding considerably less water than the lowest average calendar month; thus, if by averaging the calendar months for a period of years, it is shown that July yields the smallest amount of water, it will be found to be true that in each year there will be one or more months, not always July, — sometimes January, sometimes September, sometimes May, sometimes some other month,— which will yield less than the average for July.

If there is no storage on the stream to equalize its flow, the more rational way of arranging the monthly records for power development is to average the lowest of the months of all the years, the next lowest, and so on; that is, the months of each year should be arranged in their order of flow, and the average of all the lowest months, next lowest, etc., taken. Such an arrangement of the months has been suggested by Professor Mead in his "Notes on Hydrology," which has just appeared. This is the first suggestion of this method of arrangement that the writer has seen, and this was not known until the notes for this paper were prepared.

The average of the months in their order of flow will show for the months of low flow a much less yield than the average by calendar months, and as the total flow must be the same, the averages of the high months are materially greater than the average of the high calendar months.

A diagram showing the two methods of averaging for the Sudbury drainage area covering a period of twenty-three years is shown in Fig. 1. The full line represents the calendar averages in order of volume discharged, the dotted line the averages of the months arranged in order of flow.

A similar diagram for the Perkiomen Creek, one of the streams that has been considered as a possible source of water supply for the city of Philadelphia, is shown in Fig. 2, the records extending over fifteen years.

Some time since, in the writer's practice, it became necessary to determine what portion of time a plant requiring about 170 cubic feet per second for its full power development would be without

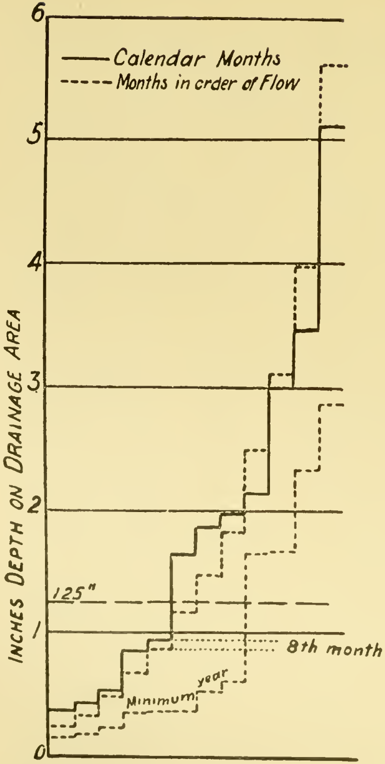


Fig. 1. Average monthly flow from the Sudbury Drainage Area for 23 years, in inches of depth on the area.

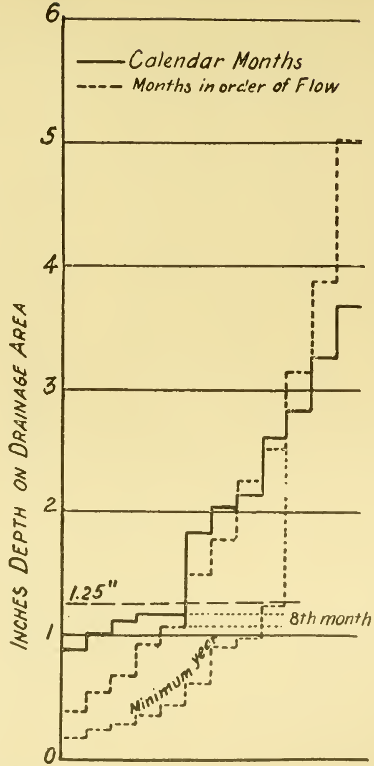


Fig. 2. Average monthly flow from the Perkiomen Drainage Area for 15 years, in inches of depth on the area

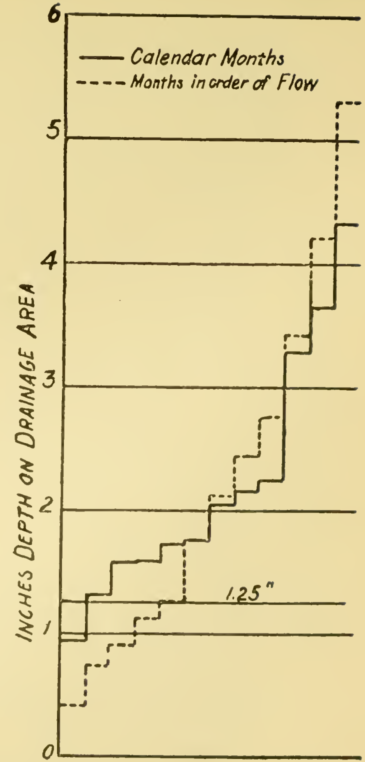


Fig. 3. Average monthly flow from the Perkiomen Drainage Area for 1887 '88, '89, '90, '91, and 93 in inches of depth on the area

full power. This plant was located on a stream not unlike the Perkiomen and of approximately the same drainage area. One hundred and seventy cubic feet per second is equivalent to $1\frac{1}{4}$ inches on the drainage area of the Perkiomen. Drawing the horizontal line on the diagram representing $1\frac{1}{4}$ inches, it is seen at once that by the average of calendar months there will be some shortage of power during five months of the year, and if the shortages for the several months are summed, it will be found that the total shortage is equivalent to full power for about three-quarters of a month. The dotted line showing the average of months in order of flow indicates that there will be a shortage for the same period, but that the aggregate shortage is nearly three times that shown by the average of calendar months.

If, now, instead of a developed plant, it be desired to consider the development of a new plant under the not uncommon rule of development, up to that flow that can as an average be counted on for eight months of the year, the diagram shows that it will be safer to develop by the dotted curve, since the eighth month by this record is lower than by the record of calendar months, and it is also plain that it will be best to compute the shortage by the record of months in order of flow.

The record by calendar months would show a proper development corresponding to a run-off of 1.17 inches, while the curves showing the months in order of flow indicate that the development should be for 1.09 inches, a not very great difference. But if the stream be developed for a flow of 1.17 inches, the calendar record indicates a shortage aggregating only fourteen days of full power, while the record arranged in order of flow indicates a shortage aggregating nearly two months of full power, or about four times the shortage shown by the calendar arrangement. Even with a development of only 1.09 inches of run-off, the months arranged in order of yield show a shortage aggregating 1.7 months of full power.

This, it will be understood, is an average condition, but it will be well to examine what may occur in a minimum year. The record of the lowest year in the 15 recorded, is shown on the diagram, and indicates that whether the development be for 1.17 inches or 1.09 inches, there will be eight months in which there will be less than full power. And if the development be for 1.17 inches, the aggre-

gate shortage will be equivalent to 4.6 months of full power. The record further shows that this may approximately occur for two or three years in succession. As this period may very likely accompany a period of business depression, it must be fully taken into account in advising the utilization of a given water-power.

The diagram for the Sudbury drainage area shows the same general condition, but the difference is less marked. If developed on a basis of the calendar month record, the shortage shown by the calendar month diagram aggregates 1.67 months of full power as against 2.2 months shown by the diagram of flow arranged in order of volume.

If the stream is developed on a basis of the lower curve, there will be a shortage aggregating two months of full power. As before, the minimum year shows a shortage extending over eight months; and if the stream be developed by the calendar record, this shortage will aggregate 5.2 months of full power; while, if developed by the record arranged by months in order of flow, the shortage will still aggregate nearly five months of full power.

It is seen from these considerations that the far more reliable method of arranging run-off records for determination of power when there is to be no large storage on a stream, is to arrange the monthly records in the order of flow rather than by calendar months. But even this is very far from the most desirable method. Particularly in the low months is the record of a whole month affected by the run-off of one or two days during or immediately following heavy storms. So that the monthly record never shows less than the power available in the stream, and practically always shows more power than can be used, since during the two or three days which bring up the total flow of a month the discharge is far in excess of that that can be used, and the greater portion of the water goes to waste.

The smallest unit of time which it is probably wise to consider is the day. Only a few daily records were available for the preparation of this paper. The best that were at hand were the records of six years of flow on the Perkiomen, the years being from 1887 to 1893, inclusive, excepting the year 1892, which was lacking. Judged by its monthly flow, the record of which was available, the year 1892 was perhaps the lowest of the seven years, while the

year 1899 was one of the two highest years observed in fifteen. The omission of the year 1892, therefore, from the record leaves the average daily flow for this period too great, but for the purpose of comparing monthly and daily records the omission is perhaps not serious.

Selecting these six years, and treating them as has been already done for the fifteen-year period of the Perkiomen, and considering for the time being only the power available for the particular plant assumed previously, namely, one requiring 170 cubic feet per second or $1\frac{1}{4}$ inches of run-off from the drainage area, the calendar month arrangement shows (Fig. 3) that there will be a shortage of power for one month only, aggregating seven days of full power, while the arrangement by months in order of flow shows that there will be a shortage during four months, aggregating about one month and thirteen days of full power, or nearly six times as much power to be supplied by steam as is indicated by the calendar month record.

But how is it when the daily record is examined? For this examination the daily flow of each year has been arranged in order of magnitude. The resulting record for the lowest year, the highest year, and the average for the six years is shown on Fig. 4. Considering again the particular plant already assumed, using 170 cubic feet per second, the diagram shows there will be a shortage extending over two hundred and eight days, or about 6.8 months instead of four months as by the monthly method, and that this shortage will aggregate about 3.2 months of full power, nearly thirteen times the amount of power to be supplied by the calendar month arrangement, and over twice that to be supplied as indicated by the monthly record arranged in order of flow.

Even this average does not tell the exact truth, because when the record of any day in any year exceeds 170 cubic feet per second all the flow above this volume tends to lift the average of the six years, but is itself unavailable for power; and to get at the exact truth, it is necessary to make an average in which the flow in every year for each day that has a larger value than 170 cubic feet per second, must be taken as only 170 cubic feet per second, until the flow of that year in which the low flow extends furthest reaches 170 cubic feet per second. Making such an average for these six

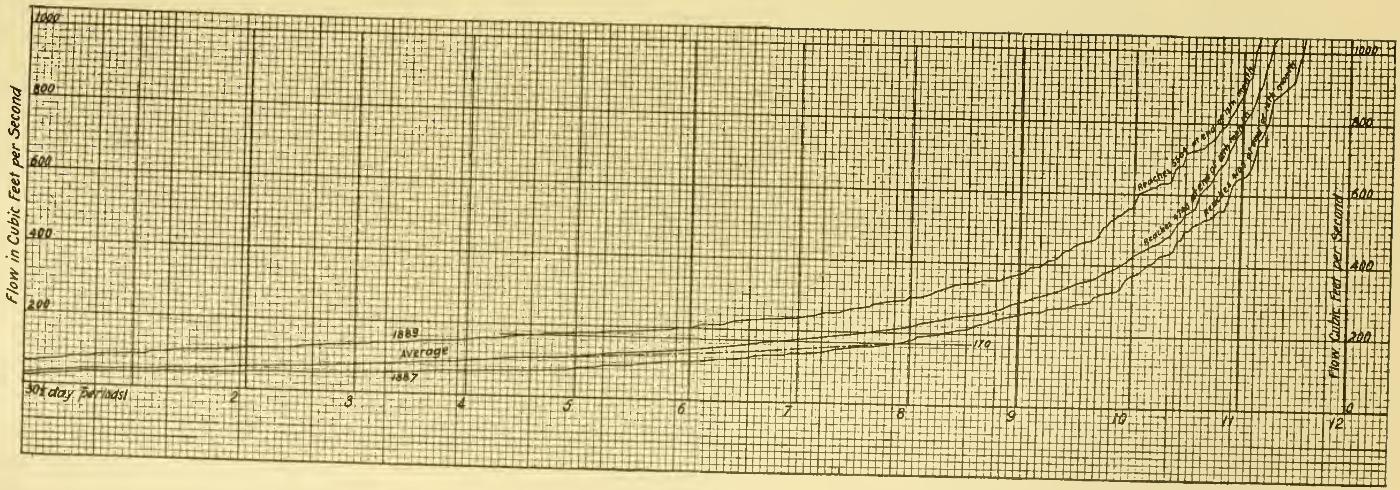

Flow in Cubic Feet per Second
1000
800
600
400
200
1889
Average
1887
170
30 day periods
2
3
4
5
6
7
8
9
10
11
12
Flow Cubic Feet per Second
1000
800
600
400
200
0

FIG. 4.

years, it is found that the shortage will extend over two hundred and thirty-seven days instead of two hundred and eight days, giving an aggregate of about one hundred days of full power to be supplied by steam.

The addition to the aggregate determined from the straight average is not large, but the cost of supplying this power is not in proportion to the amount of power supplied. If the steam plant were run constantly with not too large variations in power, the cost would perhaps be somewhat nearly proportional to the amount of power supplied, being determined largely by the quantity of fuel consumed. But where the amount of power to be supplied is very small, the labor item becomes relatively large, and the cost per horse-power hour becomes relatively greater than during those days when the steam plant is run more or less nearly up to its full capacity.

The general purpose of this paper has been to show that for streams on which there is little or no storage, the only proper way to estimate the power available for any development is to estimate it from the daily rather than the monthly flow; and to show the very considerable discrepancy that exists between the commoner method by monthly flows and the suggested method by daily flows.

FILTER OPERATIONS, INVESTIGATIONS FOR ADDITIONAL SUPPLY AND CONSTRUCTION OF NEW FILTER AT LAWRENCE, MASS.

BY MORRIS KNOWLES, CHIEF ENGINEER DEPARTMENT OF FILTRATION, PITTSBURG, PA.; M. F. COLLINS, SUPERINTENDENT OF WATER WORKS, LAWRENCE, MASS.; AND ARTHUR D. MARBLE, CITY ENGINEER, LAWRENCE, MASS.

[*Read February 12, 1908.*]

INTRODUCTION.

As is explained in the title of this paper, it is the intention, *first,* to consider the history of the operations of the old filter, which was started in September, 1893. Also, in connection with this, to tell about the changes in methods of operation and new items of construction or equipment for the old filter:

Second, to give a history of the agitation for obtaining a new supply, both by driven wells and by additional filter construction:

Third, to give a brief description of the filter and some of the items of cost which have entered into it.

HISTORY OF FILTER OPERATIONS.

In order that the history may be continuous, the method of consideration has been the same as in a paper presented before the American Society of Civil Engineers, June 5, 1901, by Morris Knowles and Charles Gilman Hyde (Trans. Am. Soc. C. E., Vol. XLVI, December, 1901). Furthermore, for the purpose of making the comparison more convenient, the numbers used to designate the present tables are the same as those given in that paper.

Population. The first table presented is called No. 1, giving the population of Lawrence, Mass., for the past seven years.

TABLE No. 1.

POPULATION OF LAWRENCE, MASS.

Date.	Enumeration by	Population.
1900	United States census.	62 559
1901	Estimated.	64 050
1902	„	65 580
1903	„	67 150
1904	„	68 750
1905	Massachusetts census.	70 050
1906	Estimated.	73 320
1907	Local census.	76 600

It is to be noticed by this table that the city has grown to a marked degree, an average of 3.2 per cent. per year. The increase is especially noticeable during the last two years, and is undoubtedly due to the completion of two large and important mill buildings in the city which has increased the number of operatives.

The need for additional water supply facilities, already somewhat evident, became markedly so as soon as it was known that these manufacturing concerns were to increase. It is an interesting study to notice how by strenuous methods, with the lack of means for supplying plenty of water, the use of this commodity per inhabitant was kept down to an unusual degree. It is quite probable that this will very soon increase with a greater amount of water available. The decrease is noticed in Table No. 4, and is graphically shown in Fig. 1, giving the use per inhabitant as ordinates with the per cent. of services metered as abscissas; the years being given for each point.

GENERAL DESCRIPTION.

The character of the water supply of the city of Lawrence, and of the Merrimac River, from which that supply is taken, is so well known that no extended description will be attempted at this time. Briefly stated, the watershed of the river has an area of 4 630 square miles and contains a population of over 500 000. Probably 60 per cent. of this population live in cities, the sewage from which is discharged in a crude state into the river. In 1901 it was estimated that in the driest times the proportion of sewage to the river water amounted to one gallon in every forty flowing past the city of Lawrence.

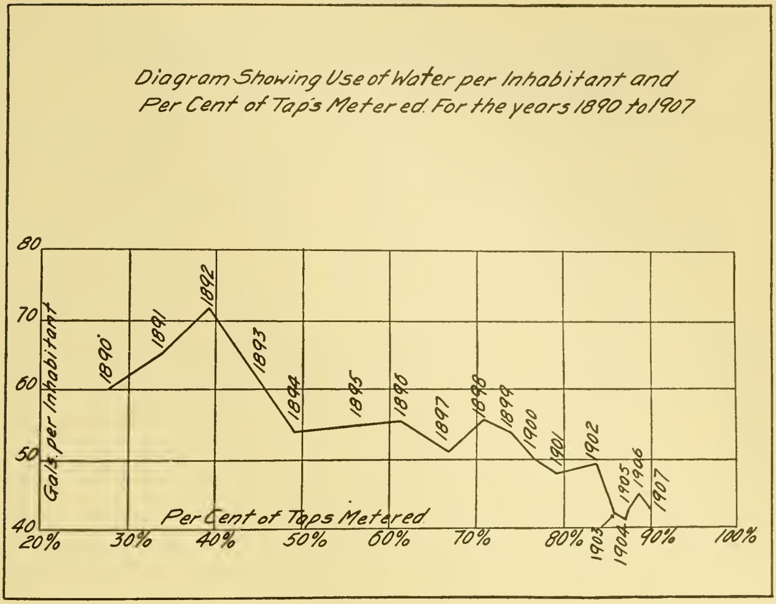


FIG. 1.

From the time of the completion of the original water works in November, 1875, to the fall of 1893, the city had been supplying this water, without purification, to its citizens.

In 1892 and 1893, after repeated outbreaks of typhoid fever, and a discussion lasting a year or more, the city took the advice of the State Board of Health and constructed a filter bed, 2½ acres in area, for the purification of its water supply. The details of this bed have been so completely covered in the paper before referred to, and so often considered in the reports of the State Board of Health, that a further description is needless.

In regard to the matters of operation, very little change has been made except in the building of the cross walls, which have divided the filter into three parts and made possible a scraping of one part while the other two are in use filtering water. There has been a change made in the method of handling the sand, throwing the dirty sand from the lower drive to the washer directly, without teaming, and this has saved some expense.

TABLE No. 4.

Average Daily Quantity of Water Pumped in Million Gallons, and Average Hours of Pumping per Day, at Lawrence, Mass., for Each Month, from 1901 to 1907.

	1901.		1902.		1903.		1904.		1905.		1906.		1907.	
Month.	Quantity Million Gals.	Hours per Day.	Quantity.	Hours per Day.	Quantity.	Hours per Day.	Quantity.	Hours per Day.	Quantity.	Hours per Day.	Quantity.	Hours per Day.	Quantity.	Hours per Day.
January	3.0	19.5	3.6	27.1	3.0	22.2	2.7	24.3	2.9	24.2	3.0	21.9	2.9	24.0
February ...	3.1	20.7	3.2	25.3	2.7	21.4	2.8	22.6	2.3	21.0	3.0	23.6	2.8	23.4
March......	2.8	17.8	4.0	25.7	2.8	21.6	2.9	22.6	2.5	22.7	2.9	23.7	2.3	20.8
April.......	2.9	17.3	3.8	23.6	2.7	18.4	3.1	23.5	3.0	23.3	2.8	21.7	3.1	23.6
May........	2.8	16.5	3.0	19.7	3.2	21.2	3.2	20.4	3.4	22.9	2.8	19.5	3.4	24.9
June	3.3	20.7	3.4	22.7	2.9	19.7	2.9	21.6	3.3	21.3	3.6	23.8	3.9	26.4
July........	3.7	22.6	3.5	21.9	3.0	20.3	3.0	20.3	3.4	22.5	3.2	21.3	3.8	26.2
August	2.9	17.3	3.2	20.6	2.7	23.2	2.8	16.8	3.4	21.5	3.8	25.2	3.9	25.8
September..	3.6	21.5	3.1	20.3	2.7	25.7	2.8	17.7	3.4	19.1	3.7	25.6	3.6	24.1
October	3.1	20.6	3.2	20.9	3.0	19.2	2.6	17.3	3.0	19.7	4.2	26.5	2.9	19.4
November ..	3.0	21.1	3.1	23.6	2.5	18.5	2.4	21.1	2.9	19.6	3.4	24.6	3.2	26.3
December...	3.0	22.1	3.2	21.2	2.7	22.2	2.6	22.9	2.9	20.3	2.9	26.2	3.2	25.5
Average per day for year......	3.1	19.1	3.4	22.5	2.8	21.2	2.8	20.7	3.0	21.6	3.3	23.1	3.3	24.2

Hours per day is sum of high and low service.

There have been times when the water in the river has not been high enough to flow by gravity to the filter, and at such times it was necessary to resort to pumping to supply water to the filter. Since January, 1900, an 8-inch centrifugal pump has been used to pump water from the filter surface in order to drain it more rapidly when preparing for cleaning. At no time has the filter been operated intermittently, with intention, since the data published in the American Society of Civil Engineers paper above referred to. The hours of pumping per day have also increased, so that the opportunities for air entering the sand have been somewhat lessened.

Use of Water. In Table No. 4 there are given, in comprehensive form, the average daily pumpage by months, including both services, and the average number of hours per day during which the

TABLE No. 5.

AVERAGE TEMPERATURES OF AIR AT LAWRENCE, MASS. ALSO THE MAXIMUM AND MINIMUM FOR EACH MONTH FROM 1901 TO 1907.

Month.	1901.			1902.			1903.			1904.			1905.			1906.			1907.		
	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
January	23.4	47	—2	23.2	54	2	24.8	48	—6	17.2	42	—23	20.2	47	—8	31.9	66	4	22.6	55	—12
February	20.3	46	2	26.0	48	0	28.0	60	—8	17.8	46	—13	18.0	44	—13	26.3	56	—5	17.1	49	—18
March	34.0	58	18	42.3	64	24	42.6	76	18	31.9	67	—1	33.0	67	4	29.0	54	4	34.3	72	—6
April	44.2	76	40	47.6	74	36	46.5	83	21	43.0	71	20	45.0	68	20	45.6	76	23	41.6	75	23
May	55.0	86	44	57.2	88	40	58.9	90	31	60.4	89	36	56.0	84	33	56.6	90	33	52.0	82	29
June	68.6	96	52	64.1	89	53	60.2	86	38	63.0	91	38	64.6	90	39	65.5	87	40	63.9	94	39
July	73.4	94	60	67.9	92	58	70.1	96	51	69.8	89	49	72.0	94	51	71.2	89	47	71.6	92	53
August	70.8	90	64	66.8	92	60	63.8	84	47	66.5	87	45	67.8	89	46	72.2	92	50	68.0	95	46
September	64.2	92	42	61.8	92	48	63.4	93	34	60.2	79	30	60.4	80	34	63.4	89	36	62.0	87	38
October	52.2	78	33	51.4	80	32	51.0	74	26	47.1	68	21	50.8	79	24	51.0	71	28	46.8	72	20
November	34.4	68	12	43.4	75	28	36.7	73	9	34.8	56	8	38.0	63	11	38.9	66	17	39.2	60	19
December	27.9	62	2	24.4	50	1	24.2	52	—14	20.7	46	—4	30.6	58	3	24.8	48	—4	32.4	62	13
Average	47.4			48.0			47.5			44.4			46.4			48.0			46.0		
Maximum		96			92			96			91			94			92			95	
Minimum			—2			0			—14			—23			—13			—5			—18

pumps were operated. As the high-service pump is only operated a few hours each day, it will be seen that in recent years the use of water during the winter months has necessitated almost constant pumping.

Temperatures. Table No. 5 contains the statistics of the temperature of the air at Lawrence, which are given for the purpose of showing the effect that this factor has upon the use of water. It will be particularly noticed that the warm winter of 1905–6, during the months of December, January, and February, aided quite a little in saving the city of Lawrence from the disgrace of pumping raw river water into the mains.

Quantity Filtered. There does not seem to be any marked difference in the quantities filtered between scrapings as compared with the earlier results, and this is probably due to the fact that there are many other factors which enter into a consideration of this problem; for it is thought that the under-drains still continue to clog and one would naturally expect lesser and lesser yields. The data obtainable upon this point are presented in Table No. 6.

TABLE No. 6.

LONGEST PERIODS BETWEEN COMPLETE SCRAPINGS OF THE LAWRENCE FILTER FOR THE SEVEN YEARS FROM 1901 TO 1907.

No.	Last Day of Complete Scraping.	First Day of Next Complete Scraping.	Length of Period in Days.	Total Quantity in Million Gallons between Scrapings.
1	March 22, 1901	April 17, 1901	27	80
2	April 20, 1901	May 28, 1901	39	121
3	Aug. 30, 1901	Sept. 25, 1901	27	103
4	Sept. 27, 1901	Oct. 28, 1901	32	99
5	Oct. 31, 1901	Nov. 25, 1901	26	83
6	March 13, 1902	April 1, 1902	20	90
7	April 2, 1902	May 1, 1902	29	120
8	May 2, 1902	June 17, 1902	44	155
9	June 20, 1902	July 10, 1902	21	80
10	July 13, 1902	Aug. 5, 1902	24	100
11	Dec. 4, 1902	Jan. 1, 1903	29	93
12	April 26, 1904	May 12, 1904	17	58
13	Nov. 27, 1904	Dec. 18, 1904	22	58
14	April 7, 1905	April 27, 1905	21	69
15	April 30, 1905	May 21, 1905	22	74
16	May 25, 1905	June 12, 1905	19	74
17	June 15, 1905	July 9, 1905	25	86
18	Dec. 6, 1905	Dec. 27, 1905,	22	64
19	April 28, 1906	May 21, 1906	24	72
20	March 28, 1907	April 21, 1907	25	78
21	May 11, 1907	May 30, 1907	20	74
22	Aug. 21, 1907	Sept. 23, 1907	34	138
23	Sept. 27, 1907	Oct. 21, 1907	25	87

Scraping. Regarding the records of scraping, which are presented in Tables Nos. 7 and 8, there is but little to be said; the average numbers seem to vary about as they did before, with an indication that the total amount of scraping removed is somewhat less than previously. It is possible that this is in part due to the lessened opportunity for scraping and a greater amount being removed each time. There is certainly a much better understanding of the necessity of regularity in scraping than previously existed, and this uniformity was shown in the later scrapings in the tables previously presented.

TABLE No. 7.

RECORDS OF SCRAPINGS OF THE LAWRENCE FILTER, ARRANGED BY BEDS FOR EACH YEAR, 1901–1907.

Bed.	1901.	1902.	1903.	1904.	1905.	1906.	1907.
1	14	14	9	10	14	16	13
2	13	14	9	10	14	16	14
3	13	14	9	10	14	16	15
4	13	13	9	10	13	16	15
5	13	14	9	10	14	16	16
6	13	15	9	10	13	16	16
7	13	15	9	10	15	16	15
8	13	15	9	9	14	16	15
9	13	15	9	9	14	16	15
10	13	13	9	10	14	17	14
11	12	13	9	10	14	17	16
12	13	12	10	10	13	17	16
13	12	13	10	10	14	17	16
14	12	13	9	10	14	17	16
15	12	13	9	10	13	17	16
16	14	13	9	10	13	17	16
17	13	14	9	10	14	17	16
18	13	14	9	10	16	16	13
19	12	13	9	10	16	16	13
20	12	12	9	10	16	16	15
21	12	13	9	10	16	16	14
22	11	15	7	10	16	16	14
23	11	15	7	10	16	16	14
24	11	14	7	10	15	16	14
25	11	13	7	10	15	16	14
Total	312	342	219	247	360	408	371
Average	12	14	9	10	14	16	15

TABLE No. 8.

Record of Scrapings of the Lawrence Filter, Arranged by Months, for the Years 1901 to 1907.

Months.	1901.	1902.	1903.	1904.	1905.	1906.	1907.
January	25	15	22	20	23	42	33
February	20	22	16	29	24	25	23
March	31	58	25	34	46	25	45
April	25	25	34	25	50	50	25
May	25	25	21	25	25	16	42
June	25	25	8	14	25	25	33
July	28	25	13	11	21	33	25
August	27	36	5	0	16	42	42
September	25	27	25	17	25	33	25
October	35	50	0	8	25	42	25
November	19	25	34	48	47	42	28
December	27	25	16	16	33	33	25
Totals	312	358	219	247	360	408	371
Averages	26	30	18	21	30	34	31

TABLE No. 9.

Depth of Sand in Inches Replaced at Crown of Each Bed of the Lawrence Filter for Years 1901–1907.

Beds.	1901.	1902.	1903.	1904.	1905.	1906.	1907.
1	10.5	8.8	10.7	4.2	9.5	8.8	3.8
2	13.9	11.5	11.1	4.3	9.2	9.3	6.5
3	15.6	12.0	11.4	4.0	10.4	10.0	8.0
4	15.0	9.8	11.9	5.7	10.7	9.3	7.5
5	14.3	9.7	10.0	6.3	10.5	8.9	7.3
6	14.4	7.3	11.8	5.9	10.3	8.8	8.3
7	14.0	10.5	9.5	6.3	7.2	9.0	6.0
8	13.0	10.0	9.5	6.0	6.9	8.8	8.8
9	10.5	9.8	10.2	6.7	6.8	8.5	5.0
10	9.0	6.5	9.8	2.8	7.0	7.8	11.5
11	8.4	4.0	10.9	3.0	7.1	8.3	12.8
12	10.1	4.0	11.0	3.2	6.7	10.5	9.0
13	10.9	4.0	11.5	6.8	6.5	10.8	8.8
14	8.5	4.0	12.7	7.0	7.5	11.0	9.5
15	9.0	4.0	12.0	4.7	7.3	10.8	7.5
16	9.2	4.0	12.3	4.5	7.7	9.0	9.0
17	11.8	4.0	11.7	4.0	8.5	8.5	9.5
18	12.5	4.0	12.5	5.1	5.5	10.3	7.2
19	8.8	4.0	13.8	4.9	5.9	10.3	7.0
20	4.5	4.0	14.9	5.4	6.2	11.0	9.8
21	7.2	4.0	14.5	5.7	6.0	10.8	8.8
22	6.8	4.0	15.2	6.3	5.9	11.0	11.2
23	7.3	4.0	15.1	7.8	5.5	11.1	12.0
24	8.0	4.0	14.8	6.4	5.0	10.0	9.2
25	8.4	4.0	11.7	4.9	5.2	10.5	8.5
Averages	10.4	6.0	12.0	5.3	7.4	9.7	8.0

Sanding. In the matter of resanding the filter, as shown in Table No. 9, there is not the same uniformity. We find that there has been a less total amount of new sand added each year. This has probably been due to the fact that, anticipating a new filter and some changes in the design of the old, it was not thought best to resand too large a quantity and have this to remove before going ahead with the new work.

The loss of head has not been regularly recorded in recent years and is not given here.

Draining. Table No. 12 gives a tabulation of the number of times the filter was drained, and although, as previously stated, there has been no intent to operate the filter intermittently, it gives an idea of the number of times it was possible for air to enter the pores of the sand.

COST OF ADDITIONAL CONSTRUCTION.

In addition to the cost items mentioned upon page 287 of the American Society of Civil Engineers' paper, previously mentioned, there have been additional items of construction carried on during recent years, *viz.*, the building of a new ice conveyor, new sand washer, and paving of driveway and slope. The most important, however, was the erection of the dividing walls, which were built in the year 1902. All of these items are given in Table No. 13, their total cost being $10 500, bringing the total cost of construction, not allowing for interest or depreciation, to $90 880. (See Plate VI. of Mr. Collins' paper.*)

TABLE No. 13.

ADDITIONAL CONSTRUCTION AT LAWRENCE FILTER FOR THE YEARS 1901–1907.
(Amounts given to nearest ten dollars.)

1901.	Widening roadway, paving, etc	$2 370
	New concrete work at slopes	500
1902.	Dividing walls, piping, etc	6 770
	New ice elevator	900
	Total	$10 540
Previous additions, 1894–1900		14 880
Original cost		65 460
	Total cost to end of 1907	$90 880

* "The Lawrence Filter," by M. F. Collins, JOURNAL NEW ENGLAND WATER WORKS ASSOCIATION, 1903, p. 288.

TABLE No. 12.

NUMBER OF TIMES WHEN THE LAWRENCE FILTER WAS DRAINED, 1901 TO 1907.

	1901.	1902.*			1903.			1904.			1905.			1906.			1907.		
		W.	M.	E.	W.	M.	E.	W.	M.	E.	W.	M.	E.	W.	M.	E.	W.	M.	E.
Total........	72	27																	
		2	2	2	15	15	15	19	16	17	25	18	22	23	20	21	17	18	17
Average per month.....	6		2.4			1.25			1.4			1.8			1.75			1.4	

* Division walls not completed until October 29, 1902. Previous to this time, in 1902, filter was drained 27 times. Letters to designated parts of the filter are: W, west portion; M, middle portion; E, east portion.

TABLE No. 14.

ITEMIZED STATEMENT OF COST OF MAINTENANCE OF THE LAWRENCE FILTER FOR THE YEARS 1901–1907.

Items.	1901.	1902.	1903.	1904.	1905.	1906.	1907.
Scraping..............................	$1 570.00	$1 990.00	$1 130.00	$1 400.00	$1 810.00	$1 870.00	$1 740.00
Scraping and sanding..................	1 010.00	530.00	1 000.00	570.00	1 020.00	930.00	990.00
Conveying.............................	850.00	1 180.00	730.00	850.00	1 070.00	980.00	1 250.00
Washing...............................	970.00	340.00	1 220.00	460.00	470.00	960.00	850.00
Removing of snow and ice..............	2 900.00	3 670.00	2 740.00	4 400.00	3 780.00	2 620.00	3 250.00
General...............................	570.00	1 130.00	980.00	1 000.00	1 630.00	2 500.00	3 460.00
Total.................................	$7 870.00	$8 840.00	$7 800.00	$8 680.00	$9 780.00	$9 860.00	$11 540.00
Per million gallons....................	6.94	7.14	7.56	8.41	8.92	8.22	9.67
Total minus snow and ice...............	4 970.00	5 170.00	5 060.00	4 280.00	6 000.00	7 230.00	8 290.00
Per million gallons....................	4.38	4.18	4.91	4.15	5.47	6.03	6.95
Special work and repairs...............	740.00	1 090.00		1 550.00	1 160.00		
Total pumpage for year in million gallons,	1 134	1 238	1 031	1 031	1 096	1 203	1 193

COST OF OPERATION.

General. The costs of operation and maintenance of the Lawrence filter were among the first to be thoroughly analyzed and published. Although the later figures exhibited but few differences (except perhaps there is a general downward tendency until the last two years), it has been thought advisable to present all of these factors, beginning with the year 1901, in order to bring these items to date. The heavier cost of operations per million gallons of the last two years is to be explained by the additional draft upon the filter capacity.

The present figures have not been looked up with the detail care employed in making up Table No. 14, on page 288 of the American Society of Civil Engineers' paper; but, as the methods of accounting were quite well established by the year 1900, it is believed that the figures now presented and taken directly from the reports of the Water Board are reliable and useful for all of these purposes of comparison. It will be noticed that figures have been presented to the nearest ten dollars.

Scraping Costs. The method of hand scraping is now so well understood that we will not attempt to give, in detail, a description of this, but, for the purpose of comparison there is presented in Table No. 15 a statement of the bed scrapings per year, together with the cost per bed and the cost per million gallons of water filtered. It is gratifying to notice that recently there has been a tendency toward a lower cost per bed, and the only reason why this has not been lower per million is undoubtedly the general lessened yield per unit between scrapings. (See Plate I, Fig. 1, of Mr. Collins' earlier paper.)

TABLE No. 15.

Statement of the Total Number of Beds Scraped per Year, together with the Cost per Bed per Scraping and per Million Gallons Filtered at the Lawrence Filter, for the Years 1901–1907.

Years.	Number of Bed Scrapings.	Cost of Scraping.	Cost per Bed for Scraping.	Cost per Million Gallons of Water Filtered.
1901.....	312	$1 570	$5.03	$1.38
1902.....	342	1 990	5.82	1.61
1903.....	219	1 130	5.16	1.10
1904.....	247	1 400	5.67	1.36
1905.....	360	1 810	5.03	1.65
1906.....	408	1 870	4.60	1.56
1907.....	371	1 740	4.68	1.46
Average	323	1 644	5.14	1.44

Washing Costs. As was previously mentioned, there has been but little change in this work except to add an additional washer in order to save some of the cost of conveying. Also, it has been arranged to throw sand from the driveway to the washer itself. Both of these have lessened to some extent the cost per cubic yard, and it is a pleasure to record that there is a general downward tendency in this factor. The details of this classification of accounts are given in Table No. 16. (See Plate I, Fig. 1; and also Plate I, Fig. 2, of Mr. Collins' earlier paper.)

TABLE No. 16.

Detail Costs of Sand Washing Operations at Lawrence Filter for the Years 1901 to 1907.

Year.	Cost of Operations.			Cubic Yards Washed.	Cost per Cubic Yard.
	Labor.	Bills.	Total.		
1901	$870	$100	$970	2 024	$0.48
1902	340		340	885	.38
1903	1 170	50	1 220	3 046	.40
1904	440	20	460	1 170	.39
1905	470		470	1 500	.31
1906	670	290	960	2 877	.33
1907	850		850	2 192	.39

Snow and Ice Costs. There is but little need to comment upon these items of cost, which are given in Table No. 14; the method remains the same and the expense is fully as great as ever, much in excess of the interest on a sum of money needed to cover the present filter, and a yearly tax of from $2.50 to $4.00 per million gallons. This excessive expense for the three winter months of the year is an exorbitant one, which should not be endured any longer than is absolutely necessary. (See Plate II of Mr. Collins' earlier paper.)

RESULTS OF FILTRATION.

Chemical. In the matter of chemical results there is but little change from the previous determinations. It appears that the color in the effluent is somewhat higher than during the previous six years, as is also chlorine, in both river water and effluent.

Fig. 1. Transporting Scraped Sand from Filter to Washer.

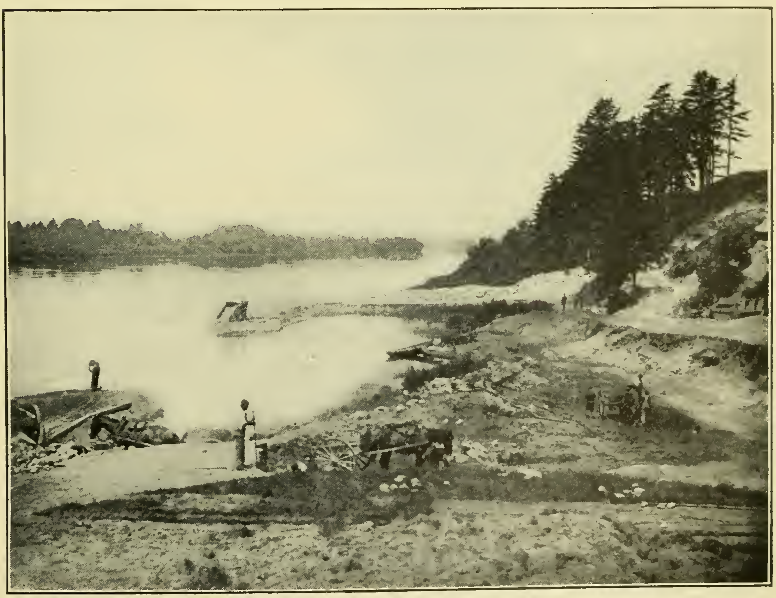


Fig. 2. Site of Filter, showing Work on Embankment, Jan. 28, 1906.

TABLE No. 17.

RESULTS OF CHEMICAL ANALYSES OF APPLIED MERRIMAC RIVER WATER AND EFFLUENT FROM LAWRENCE FILTER FOR THE YEARS 1901 TO 1907 (PARTS PER MILLION).

Year.	Yearly Rainfall in Inches.	COLOR.			AMMONIA.						CHLORINE.		
					Free.			Albuminoid.					
		River.	Effluent.	Per Cent. Removed.	River.	Effluent.	Per Cent. Removed.	River.	Effluent.	Per Cent. Removed.	River.	Effluent.	Per Cent. Removed.
1900	45.58	4.1	3.5	15	0.109	0.078	28	0.190	0.077	59	2.1	2.1	0
1901	45.53	5.1	4.6	10	0.111	0.103	7	0.226	0.102	52	2.5	2.5	0
1902	46.88	4.7	4.9	—4	0.081	0.091	—12	0.200	0.095	52	2.4	2.6	—18
1903	38.09	4.1	4.2	—3	0.09	0.098	—9	0.194	0.082	58	2.8	2.9	—4
1904	38.83	3.9	4.4	—13	0.126	0.125	1	0.216	0.092	57	3.2	3.3	—3
1905	35.32	4.1	4.7	—15	0.133	0.122	8	0.240	0.109	55	3.3	3.6	—9
1906	39.71	3.8	4.0	—5	0.128	0.105	7	0.211	0.089	56	3.5	3.5	—6
1907	37.25	3.9	3.9	0.0	0.146			0.237			3.2	3.3	—3
Average, 7 years	40.23	4.2	4.4	—4	0.116	*0.107	*0.3	0.218	*0.095	*55	3.0	3.1	—6
Average 6 previous years	38.85	4.7	3.8	11.6	0.089	0.092	—3.4	0.199	0.094	52.8	2.2	2.4	—9

(*Continued on following page.*)

TABLE No. 17 — *Continued.*

Year.	Hardness.			Nitrogen.						Oxygen Consumed.		
				Nitrites.			Nitrates.					
	River.	Effluent.	Per Cent. Removed.	River.	Effluent.	Per Cent. Removed.	River.	Effluent.	Per Cent. Removed.	River.	Effluent.	Per Cent. Removed.
1900	12	16	—33	0.002	0.001	50	0.11	0.38	—260	4.3	2.4	44.2
1901	12	17	—42	0.002	0.001	50	0.15	0.40	—167	5.7	3.6	36.8
1902	12	14	—17	0.001	0.000	100	0.13	0.28	—115	5.4	3.8	29.7
1903	14	20	—43	0.002	0.001	50	0.13	0.32	—146	4.8	3.2	33.3
1904	17	21	—24	0.003	0.000	100	0.16	0.40	—150	5.4	3.7	31.5
1905	13	18	—38	0.003	0.001	67	0.16	0.38	—143	6.2	4.2	32.3
1906	11	14	—27	0.003	0.001	67	0.14	0.34	—127	5.8	3.6	38.0
1907	11	17	—55	0.003			0.14			6.3		
Average, 7 years	13	17	—35	0.002	*0.0007	*72	0.14	*0.35	*—141	5.7	*3.7	*29
Average 6 previous years	14	21	—50	0.002	0.001	50	0.14	0.40	—190	4.2	2.8	33

* Average for six years, figures for 1907 not obtainable at this date.

The same may also be said in regard to the nitrogen determinations, except the nitrates. In fact, there seems to be a gradual increase in the organic impurities in the river water, and this is also seen in the bacterial determinations. Table No. 17 gives the general chemical determinations, in the form of averages for each year, together with the percentage removed for each constituent and the averages for whole seven-year period, compared with average of the previous six years.

Bacterial. It appears there has been an increase of the bacteria contained in the river in the last seven years, but it is gratifying to note that there is no increase in the numbers found in the filtered water. In fact, it may be asserted with safety that, in general, numbers are lower than ever, with an accompanying greater degree of purification.

There is, however, one notable fact, and that is that there does not seem to be a further reduction of bacteria in the passage of the water through the pipe system of the town, and the tap at City Hall very frequently shows bacteria no lower, and sometimes a few higher, than in the effluent from the filter.

A truer indication, however, of the work of the filter is shown by the coli determinations, and it is gratifying to note that the numbers of times that these organisms were found in one cubic centimeter of the filtered water is low.

DEATHS FROM TYPHOID FEVER AND GENERAL DISEASES.

By many the true benefit of the filter is considered to be best represented by the number of cases of and deaths from typhoid fever, and by the total death-rate of the community. There are some other factors in Lawrence, however, which are likely to produce typhoid fever, among which may be mentioned the polluted canal water supply; also the cases by importation and contact, and secondary infection from these. These causes are not, however, anywhere near as strong in Lawrence as in some communities, but we are reminded by the recent investigations in Washington, D. C., not to place too much reliance on the typhoid fever death-rate.

In order that we may have these figures at hand, there are given in Table No. 21, the number of cases and deaths from typhoid fever

TABLE No. 18.

NUMBER OF BACTERIA IN THE WATER OF MERRIMAC RIVER, IN EFFLUENT OF FILTER AT PUMPING STATION, AND IN TAP WATER AT CITY HALL.

	Total River Water Applied to Filter.	Total in Effluent at Pumping Station.	Per Cent. of Reduction Passing through Filter.	Total Bacteria per c.c. in Tap Water at City Hall.	Number B. Coli per c.c. in River Water.	Per Cent. of Samples Containing B. Coli per 1 c.c. in Effluent.	Per Cent. of Samples Containing B. Coli found in City Hall Tap.
1900.							
January	12 800	110	99.1	83	89	41	15
February	12 100	73	99.4	52	57	10	0
March	5 000	36	99.3	50	316	8	0
April	3 300	27	99.2	28	43	0	0
May	3 200	70	97.8	23	50	40	0
June	1 250	68	94.6	43	184	17	0
July	3 900	35	99.1	39	59	0	0
August	7 700	17	99.8	12	101	20	0
September	19 200	18	99.9	27	179	14	0
October	15 500	72	99.5	50	34	0	0
November	16 800	58	99.7	60	127	12	0
December	5 600	64	98.9	40	108	37	12.5
Average	8 970	54	99.4	43	87	17	2.3
1901.							
January	5 600	61	98.9	34	92	11.1	37.03
February	2 500	24	99.0	32	82	13.04	0.0
March	8 900	50	99.4	26	69	17.64	0.0
April	1 400	15	99.0	17	34	0.0	0.0
May	1 400	8	99.4	9	20	0.0	0.0
June	3 000	58	98.0	25	22	25.0	0.0
July	1 760	11	99.4	12	11	0.0	0.0

August	1 580	18	98.9	14	7	0.0	0.0
September	1 760	15	99.1	9	9	0.0	0.0
October	1 900	22	98.8	11	10	0.0	0.0
November	1 300	7	99.5	6	5	0.0	0.0
December	5 100	22	99.6	26	8	0.0	0.0
Average	3 017	26	99.1	18	10.2	10.5	3.1
1902.							
January	7 300	47	99.4	58	21	4	0
February	7 400	44	99.4	51	45	4	0
March	4 500	61	98.6	64	20	6	0
April	4 200	75	98.2	66	16	0	0
May	3 300	30	99.1	26	28	0	0
June	2 700	32	98.8	40	55	0	0
July	3 700	35	99.9	57	161	0	0
August	20 900	324	98.4	112	219	14	0
September	15 300	23	99.8	66	104	0	0
October	10 000	105	98.9	125	53	0	0
November	4 300	25	99.3	103	83	0	0
December	7 000	109	98.4	96	72	8	8
Average	10 300	76	99.3	72	73	4	1
1903.							
January	12 500	58	99.5	71	32	0	0
February	7 000	33	99.5	75	23	4	0
March	4 100	20	99.5	38	40	8	4
April	2 200	12	99.5	19	24	8	8
May	4 100	18	99.6	24	58	0	0
June	18 200	14	99.9	45	141	0	0
July	3 800	18	99.5	27	68	25	0
August	4 000	17	99.6	50	66	20	0
September	38 400	20	99.9	41	141	0	0
October	40 300	29	99.9	85	178	0	0
November	5 300	32	99.4	33	70	88	0
December	14 500	110	99.2	85	95	4	4
Average	12 900	32	99.7	49	78	4.2	1.7

TABLE No. 18.— *Continued.*

NUMBER OF BACTERIA IN THE WATER OF MERRIMAC RIVER, IN EFFLUENT OF FILTER AT PUMPING STATION, AND IN TAP WATER AT CITY HALL.

	Total River Water Applied to Filter.	Total in Effluent at Pumping Station.	Per Cent. of Reduction Passing through Filter.	Total Bacteria per c.c. in Tap Water at City Hall.	Number B. Coli per c.c. in River Water.	Per Cent. of Samples Containing B. Coli per 1 c.c. in Effluent,	Per Cent. of Samples Containing B. Coli found in City Hall Tap.
1904.							
January	10 100	70	99.3	55	62	4	0
February	7 200	55	99.2	36	51	12.5	8.3
March	4 000	33	99.2	46	23	0	0
April	2 700	20	99.3	57	12	0	0
May	3 100	16	99.5	24	53	0	0
June	5 600	22	99.6	44	70	0	0
July	8 000	11	99.9	35	125	25	25
August	3 500	14	99.6	135	34	40	0
September	19 400	16	99.9	45	129	0	0
October	5 600	26	99.5	60	93	0	0
November	15 600	90	99.4	43	110	10.5	10.5
December	17 900	75	99.6	65	115	4	0
Average	8 600	37	99.6	55	73	8	3.6
1905.							
January	14 200	110	99.2	70	101	20	0
February	14 800	55	99.6	33	125	0	0
March	10 300	55	99.5	55	98	0	0
April	3 600	170	95.3	60	38	8.7	4.3
May	1 900	12	99.4	34	26	0	0
June	9 600	9	99.9	23	60	0	0
July	3 900	55	98.6	75	57	0	0

August	19 500	37	99.8	51	272	33.3	17.6
September	13 500	44	99.7	53	189	10	0
October	39 800	110	99.7	65	169	0	0
November	8 700	70	99.2	70	160	0	37.5
December	11 500	24	99.5	46	122	0	0
Average	12 600	63	99.5	53	155	6	4.1
1906.							
January	8 600	52	99.4	55	105	7.4	7.4
February	6 400	38	99.4	23	80	0.0	0.0
March	5 400	22	99.6	26	57	3.7	0.0
April	3 200	19	99.4	26	31	4.5	0.0
May	1 600	16	99.4	26	51	0.0	0.0
June	1 000	6	99.4	60	59	25.0	0.0
July	6 200	18	99.7	70	143	0.0	0.0
August	4 100	13	99.7	35	1 160	0 0	25.0
September	2 600	11	99.6	60	61	0 0	0.0
October	5 200	12	99.8	110	85	0 0	20.0
November	1 900	11	99.4	22	44	0 0	0.0
December	2 900	20	99.3	16	153	0.0	0.0
Average	4 092	20	99.6	36	165	3.4	4.4
1907.							
January	3 900	33	99.2	45	101	9.1	0.0
February	3 000	18	99.4	20	54	0.0	0.0
March	3 200	19	99.4	39	58	3.4	0.0
April	2 200	14	99.4	19	25	0.0	0.0
May	700	9	98.7	12	42	0.0	0.0
June	950	10	98.9	8	69	0.0	0.0
July	2 600	20	99.2	48	62	20.0	0.0
August	3 000	29	99.0	19	168	0.0	0.0
September	5 700	22	99.6	38	87	25.0	0.0
October	1 400	10	99.3	16	105	0.0	0.0
November	3 300	22	99.3	54	140	4.4	0.0
December	3 400	26	99.2	23	100	3.3	0.0
Average	2 800	19	99.3	28	84	5.5	0.0

in the city of Lawrence, together with the rate per 10 000 and percentage of cases resulting in death; the total death rate in the city of Lawrence; the typhoid fever and total death-rates in the state of Massachusetts are also given as far as obtainable. The averages of the same data by years given in the former paper, for the six years prior to construction and the six years following construction, are shown for comparison with the average of the last seven years. The last figure shows remarkable uniformity, except for two years, 1903 and 1907,* the death-rate being kept well down, and it is indeed a gratifying result. It is also interesting to note the reduction in whole state, as well as the reduction in general death-rate in both state and city.

TABLE No. 21.

Reported Cases of Typhoid Fever and the Deaths Resulting therefrom for the Years 1901 to 1907; also the Deaths from all Diseases and same Facts for the State of Massachusetts.

Year.	Number of Cases.		Number of Deaths.		Percentage Resulting in Death.	All Diseases, Death-Rate per 10 000, Lawrence.	Typhoid Death-Rate, Mass.	All Diseases, Death-Rate per 10 000, Mass.
	Total Reported.	Per 10 000 Population.	Total Reported.	Per 10 000 Population.				
1901	100	15	12	1.8	12	170.8	2.0	168.6
1902	102	15	11	1.6	11	177.3	1.9	162.1
1903	149	21	20	2.9	13	178.4	1.8	161.3
1904	61	9	10	1.4	16	165.9	1.6	154.7
1905	98	14	15	2.1	15	195.9	1.9	167.7
1906	105	14	13	1.7	12	182.8	1.6	166.1
1907	129	17	21	2.7	16	188.9	...	.....
Average	106	15	15	2.0	14	180.0	...	.....
†Average 6 years previous	188	43	53	12.0	28	.....	4.0	198.3
‡Average 6 years after	84	15	14	2.6	18	.....	2.6	183.3
Per cent. reduction	55	65	72	78	35	.....	...	.....

† Previous to construction of filter.
‡ After construction of filter.

STUDIES FOR ADDITIONAL SUPPLY.

The successive moves made by the Water Board and the city councils, before an appropriation was granted for construction of

* See discussion by M. F. Collins.

the new filter, form an interesting record of the ways of municipal activities. For some years the officials of the Water Department had been on the anxious seat, due to the lack of filter capacity, and many times the reservoir has been almost drained in the winter time.

In looking back over the history it seems almost incredible that this critical state of affairs should not have been recognized by every one and that each willing shoulder should not have been put to the wheel in making for progress and in obtaining something which could be accomplished within a reasonable time rather than to experiment upon ideas or conjecture.

1902 Agitation. The annual report of the Water Board for 1901 was the first to call attention to the imperative demand for additional filter capacity. Upon July 2, 1902, a joint meeting of the city councils was held to consider the need of the new filter, which meeting was addressed by Hiram F. Mills, civil engineer, member of the State Board of Health. The suggestions then made were that the old filter be covered and that a new one be located to the west of the old. It is interesting to note that this period is just about ten years after the first appropriation for the old filter. The meeting did not result in anything tangible. Councils inspected the old filter upon July 9 and, as the suggestions did not seem to be heeded, Mr. Mills thought advisable upon July 10 to transmit a letter of warning.

On July 11, 1902, the Water Board voted to construct the dividing walls which had been recommended by Mr. M. F. Collins, then "care-taker of the filter," in the annual report for 1900, and again advocated during this year. It was decided not feasible to cover the old filter at this time, but it was also voted to place meters on all services. On the 11th of the month, the city council voted $5 000 for the walls, and on the 25th, the contract was awarded to Joseph Wagenbach & Son for $3 322.78. The total cost of the work complete, including that done by the department, was $6 767.60.*

On August 7, the State Board of Health addressed a letter to the mayor and city councils advising that more complete steps

* See paper on "The Lawrence Filter," by M. F. Collins, JOURNAL NEW ENGLAND WATER WORKS ASSOCIATION, 1903, p. 288, for description and illustrations.

should be taken, as the walls would be of insignificant advantage, and other means of increasing the supply were urgently needed. The work of building walls was completed, so as to use the beds in sections on October 8, 1902, and advantages in the operation resulted, with less anxiety in the winter season.

1903 Agitation. The question of additional filter area was again recognized and came to the front in the first of the year 1903. The Water Board once more called attention to the condition and said that something should be done at once. Early in March it was arranged to have plans and specifications prepared for the new filter, and on March 14 surveys were begun by the city engineer for the purpose of securing the necessary information and data upon which to plan this work. During the latter part of the month a request was made of the city councils for an appropriation of $60 000. Notwithstanding all of this agitation and discussion, however, and the recommendations of leading citizens as to the necessity, the city councils withheld their approval, on the grounds of insufficient funds.

1904 Agitation. During the winter of 1903–4 conditions became so critical, the reservoir was so very low, and the accumulation of ice upon the filter so great that the yield grew less than ever. The State Board of Health, on February 17, warned the Water Board that dire results would follow if steps were not taken to husband the supply and curtail all possible waste. It was recommended, if stringent restrictions failed to give relief, that the Board should ascertain if water could not be obtained from either of the surrounding towns. Conferences were held for this purpose, but no action resulted thereform. Thereupon, the president and superintendent of the Water Board appeared again before councils, with a request that money be furnished to provide for building a filter according to the plans which had already been approved by the State Board of Health. Restrictive measures were helpful, as is shown by the lessened use of water.

Shortly after this, communications were received from two filtration companies, advocating certain special types of filters at lesser cost. There was considerable delay in considering the various plans and the impossibility of securing a new filter before winter was realized.

The driven-well proposition was first suggested about this time; a communication was received, April 21, 1904, offering to supply 2 000 000 gallons daily from wells to be driven on the south side of the river, nearly opposite the pumping station; however, nothing was done. The city government next endeavored, through the Water Board, to obtain water from adjacent towns, which request was made in the month of September, 1904. The result was a refusal of each town, on the ground that such action would be illegal.

1905 Agitation. The same condition continued during the winter of 1904–5, barely enough water being filtered to supply the daily need. There was no reserve in cases of emergency, but fortunately no extraordinary drain taxed the filter. Early in January of this year the joint standing committee on water works of the city council, together with the Water Board, were constituted a committee to determine whether a suitable supply could be obtained by driven wells. These investigations continued in many places for some months and lasted into the fall of the year. It is surprising, notwithstanding the correct knowledge of the usefulness of the filter and in face of opinions of the city engineer and superintendent of water works that suitable well water could not be obtained in sufficient quantities, and with only two days' supply in the reservoir on March 14, 1905, that public sentiment allowed such dillydallying in this important matter.

Wells were drilled in many places, — up the Merrimac River near Pine Island, in the easterly portion of the city at Sow Brook, on the south side of the Merrimac River as far south as Cold Spring, and in the Shawsheen Valley in Andover. Some of the wells did not produce sufficient water and some contained too much carbonic acid or too much iron. For one reason or another none of the sources were found suitable. It seemed, however, to be against public opinion to give up the idea of well water, even when the drilling concern had acknowledged the improbability of success, and the investigations were continued and more money spent. Many reports were received from well-drillers, from interested persons, and from the State Board of Health; the latter finally concluded that none of the places considered were acceptable for the purpose of obtaining a water supply. The total cost of these

experiments and studies was $5 764.44, and they extended over a period of eight months and into the late fall.

During the early spring, and about the time it was first thought of obtaining water from driven wells, the water supply committee of the legislature held a hearing, at which it was recognized that conditions at Lawrence were deplorable. Although the hearing developed these conditions, the city government was given one week to act. Upon failure to so do, the legislature ordered the city of Lawrence, through its mayor and board of aldermen, to construct, within a year, an adequate filter, or temporarily obtain water from the surrounding towns. This legislative act is so unusual that it is given as follows:

Chapter 389 of the Acts and Resolves of Massachusetts Legislature of 1905.

An act to provide for an increased water supply for the city of Lawrence.

Be it enacted, etc., as follows:

Section 1. The city of Lawrence, acting through its mayor and aldermen, shall forthwith increase the capacity of its works for filtering the water of the Merrimack River to such an extent as to insure at all times a sufficient quantity of water for the use of the public in that city, or it may take water from any spring, pond, or well, in Andover, North Andover, Tewksbury, or North Reading; provided, that no source of water supply for domestic purposes shall be taken or used under this act without the approval of the State Board of Health, and that the location of all filter galleries and wells, and the design of filters, shall be approved by the State Board of Health; and provided, further, that if water shall be taken directly from any pond or stream other than the Merrimack River, it shall be used only for the period of one year from the date of the passage of this act, and only in such quantities as the State Board of Health may deem necessary.

Sect. 2. Said city is hereby authorized and directed to raise and appropriate, in such manner as the city council shall determine, such sums of money as shall be requisite for carrying out the provisions of this act; and, if the city council shall so determine, the city may incur indebtedness for the purpose of obtaining money to such an amount as may be necessary for carrying out the provisions of this act, and may issue bonds, notes, or scrip therefor.

Sect. 3. The city of Lawrence shall pay all damages to property that may be sustained by any person or persons by the taking of the waters of any stream or pond as authorized by this act, or insofar as the said city may diminish the flow in any stream or pond, or by the taking of any land, rights of way or easements, or by the erection of dams or the construction of any aqueducts, waterways or other works for the purposes of this act; and such damages shall be assessed and determined in the manner provided by Chapter 48 of the Revised Laws.

Sect. 4. The towns of Andover, North Andover and Methuen, or any one of them, are hereby authorized to contract with the city of Lawrence for a supply of water upon such terms and for such periods of time, not exceeding one year from the date of the passage of this act, as may be agreed upon by the mayor and aldermen of said city and by the selectmen of the town entering into the contract.

Sect. 5. The supreme judicial court shall have jurisdiction to enforce the provisions of this act.

Sect. 6. This act shall take effect upon its passage. (Approved May 10, 1905.)

Inquiries made during the early summer and formal requests made to each of the towns of Andover and North Andover in the late fall, brought the same results as before, namely, that no relief was to be obtained from these sources. The prevalent belief among the officials of these places seemed to be that such temporary arrangements would be used to secure permanent rights.

In August, 1905, it was suggested that the cleaning of the under-

drains of the filter, such as had been done at a prior date, in 1899 and in 1900, would be a benefit. A few drains were examined, disclosing about the same character of clogging material as was noticed when this work was done before. The project was abandoned, however, for fear that disturbance at this time would be unwise.

1906 Results. The winter of 1905–6 was less severe than the few previous ones, so that the conditions did not reach such a critical stage. In the spring of 1906, however, the agitation for a new filter was renewed, after more legislative and public hearings, in which the conditions and need of a new filter were made plain. The legislature, through its Committee on Water Supply, discussed taking action, but waited, giving the city opportunity. After some discussion, upon March 28, 1906, the city council authorized a loan of $70 000 for the construction of a filter. Upon May 25, 1906, bids were received and contract awarded to Michael O'Mahoney, a long-time Lawrence citizen, for the construction of a filter, at an estimated total of $47 543.

The work was started on May 28, 1906, with every prospect that the filter would be in use by November 15, the date set for its completion. Many delays, however, occurred, as the contractor had to abide by an ordinance of the councils to use local labor entirely; and in the early part of November it became evident that completion on time was not possible, and the city councils gave the contractor permission to employ labor from outside the city. Winter came on, however, with the filter uncompleted, and as the winter was a severe and cold one, there was no alternative left but to again apply to the neighboring towns for a temporary supply. In order that the previous objection of illegality could not now be brought up, there was an enabling act passed by the legislature authorizing such temporary use.

Temporary Supply. This action in obtaining water from the surrounding towns is an interesting example of what can be done under pressure. Upon December 16, 1906, the Water Board called attention to the danger and the immediate necessity for securing an additional supply. Upon December 18 there was a conference with the officials of North Andover, and a special election was ordered upon January 1, 1907. The vote, however, was strongly

against supplying the city of Lawrence with water. A special election was authorized in Andover upon January 7, and the vote was almost unanimous in favor of giving aid. The water from Andover was turned into the city main on Friday, January 11.

On February 5 attention was again called to the low water in the reservoir, and upon February 6 a conference was held in Boston, between a local committee from the Lawrence city government and the Water Supply Committee of the legislature, together with members from the State Board of Health. Recognizing the necessity, a bill was introduced and passed in the legislature upon February 7, and signed immediately by the governor, which authorized the town of North Andover to temporarily supply the city of Lawrence with some water from Great Pond. Upon February 14, water from the town of North Andover was turned into the piping system of the city of Lawrence, and, with this help, the water in the reservoir gained and was not again lowered to the danger limit. There was about 50 000 000 gallons obtained from Andover, at a total cost of about $4 500. There was about 37 000-000 gallons obtained from North Andover, at a cost of about $5 500, making the total expense to the city of Lawrence for this lack of forethought and lack of paying attention to proper advice, $10 000, which includes cost of connections.

On April 3, 1907, occurred an accident which caused a set-back in the progress. This was due to a section of the filter roof collapsing, which will be considered in detail by Mr. Sanford E. Thompson.

The entire filter was completed and water turned on November 5, 1907, about one year behind time. At first the filter was run at a slow rate and it was about two months, or January 4, before the State Board of Health allowed the water to be used as a drinking supply by the people, and it is advised that for some time the rate of filtration shall not exceed 1 000 000 gallons per day.

DESCRIPTION OF THE NEW LAWRENCE FILTER.

General. This filter is located directly west of the old one; a portion of it is south of the boiler house and comes close to the foundation. It extends westward, covering an area of about three quarters of an acre. It also extends out into the river bed

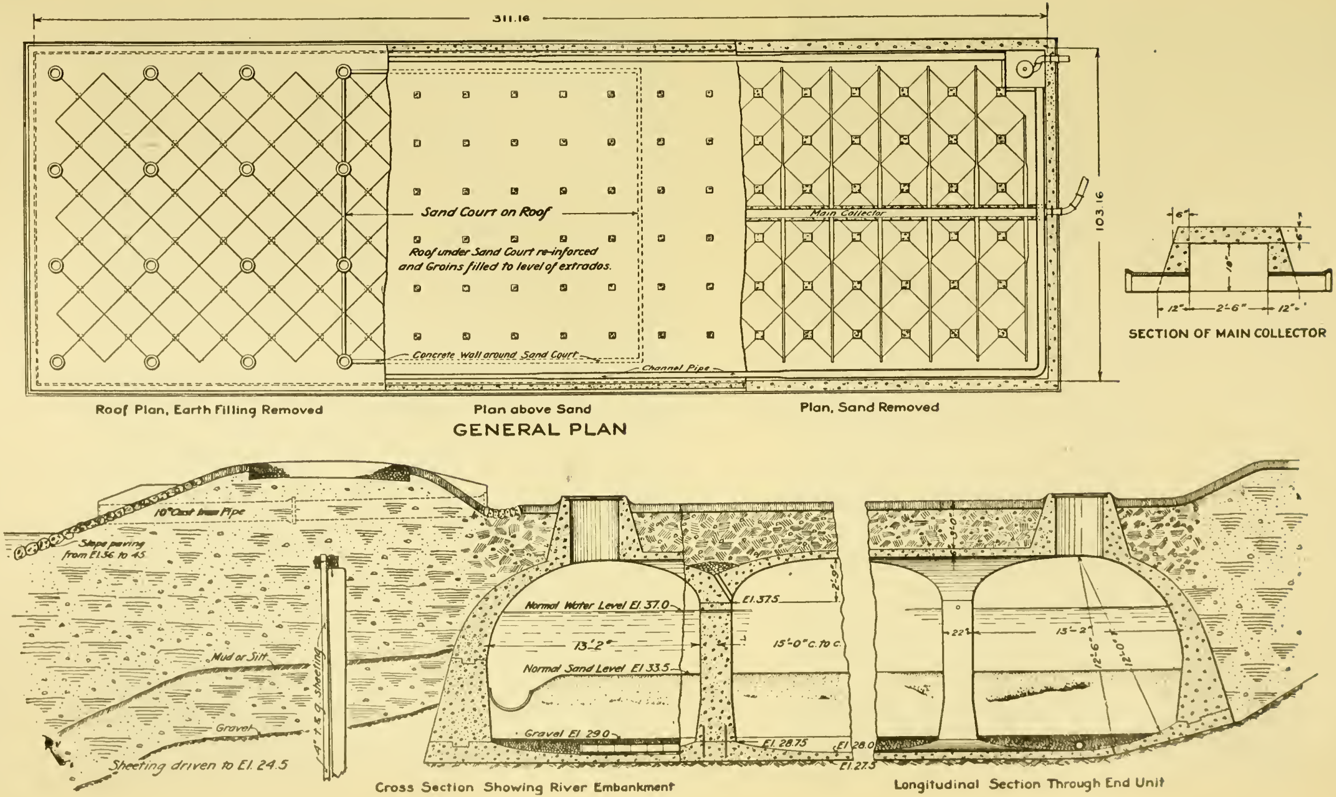

311.16
103.16
Sand Court on Roof
Roof under Sand Court re-inforced and Groins filled to level of extrados.
Main Collector
Concrete Wall around Sand Court
Channel Pipe
Roof Plan, Earth Filling Removed
Plan above Sand
Plan, Sand Removed
GENERAL PLAN
SECTION OF MAIN COLLECTOR
12"
2'-6"
12"
6"
10"
Slope paving from El. 36 to 45
10" Cast Iron Pipe
Mud or Silt
Gravel
4" T. & G. sheeting
Sheeting driven to El. 24.5
Normal Water Level El. 37.0
Normal Sand Level El. 33.5
13'-2"
15'-0" c. to c.
El. 37.5
Gravel El. 29.0
El. 28.75
El. 28.0
El. 27.5
22"
13'-2"
12'-6"
12'-0"
Cross Section Showing River Embankment
Longitudinal Section Through End Unit

Fig. 2.

and a new embankment was constructed along the shore of the river from the material of excavation. (See Plate I, Fig. 2, and Plate II, Fig. 1.) The amount of excavation was about 35 000 cubic yards, and the concrete amounted to about 2 900 cubic yards.

The filter is 21 bays long and 7 bays wide, the bays being 15 feet from center to center of the piers. A general plan and sections are shown in Fig. 2. There are various manholes in the roof for the purpose of letting light into the filter and also to serve as ventilators. Originally it was intended to have the usual sand incline and entrance in the easterly end that has commonly been constructed for filters of this type. With the advances in the method of handling sand, it was thought that it would never be necessary to use wheelbarrows; therefore, a rectangular monitor entrance was constructed, by which it will be possible to have access into the filter. For the purpose of taking out sand that has been scraped it is proposed to use pipe lines in connection with the ejector system. In addition to this, and in order to provide for a storage place for sand upon the roof, an area of 6 bays each way, in the middle of the filter, was reinforced with cross lines of $\frac{3}{4}$-inch steel rods, spaced 9 inches apart, center to center, and also an additional amount of 3 inches of concrete was placed over the entire surface and leveled over the piers, with a filling of cinders 12 inches thick and a concrete pavement on top. Concrete walls were also placed about this area in order that the sand should be confined and not scattered over the sod which will cover the remainder of the roof. Sand will be returned through the openings in the roof. (See Plate II, Fig. 2.)

The river embankment has a core of sheeting in order to make it tight and to aid in keeping the water out during the construction. Some water was encountered in the bottom, but an 8-inch pump working part of the time was sufficient to take care of it. The sub-grade was generally of good material, especially when the ground was well drained. Some little trouble was occasioned in a few places in placing concrete on the bottom; these places were later thoroughly repaired. In order to take care of the upward pressure of the water whenever the filter may be drained while the river is high, gravel drains were laid to pipes all coming

FIG. 1. Cofferdam Construction and Excavation, August 9, 1906.

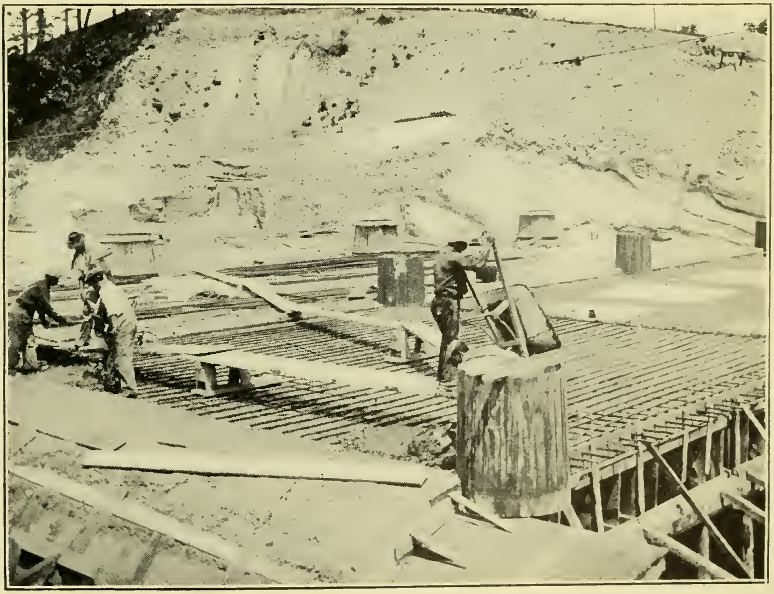


FIG. 2. Method of Reinforcing Roof for Storing Sand, July 5, 1906.

into one central pipe 24 inches in diameter and filled with coarse gravel. This pipe projects upward through the floor and through the bed of sand. This will allow the pressure under the floor to be relieved and the excess water to flow out over the surface of the sand in case such conditions occur.

Details. The details of the filter construction are those of the usual type of groined arch roof, with inverted groined floor, taking the load from piers spaced 15 feet apart. The roof is 6 inches thick at the crown, with a rise of 2 feet 9 inches and a depression at the piers of 20 inches. The floor is 6 inches thick midway between piers, with a greater thickness of 15 inches underneath the piers. The piers are 22 inches square, with chamfered corners, and battered below the sand line so that they are 30 inches square at the base. The water which collects upon the roof of the filter, and above on the slope, will be taken down through openings in the piers and be filtered.

Water is brought to the filter from the gate house which supplies the old filter through a 20-inch pipe, and in through a controlling valve operated by a float, upon the surface of the sand. In order to thoroughly distribute the water and not cause disturbance of the sand, half-channel pipes are placed along the sides of the filter to receive the water as it comes in the inlet channel. (See Plate V, Fig. 2.)

The main drain which takes the water away from the filter is a concrete structure of box shape, with vertical sides and a flat slab roof; it is large enough for a man to crawl through. Twelve-inch half-tile pipes enter this at the center of each bay and extend one bay toward the side walls. From this point there are 6-inch pipes entering these 12-inch half-pipes. (See Plate VI, Fig. 1.)

The filter sand is supported on the drainage gravel, which averages 1 foot in depth. The lower 7 inches ranges from about 3 inches to $1\frac{1}{4}$ inches in size. The next $2\frac{1}{2}$ inches in depth is of gravel running from $1\frac{1}{4}$ inches to $\frac{3}{8}$ inch. Above this there is $1\frac{1}{2}$ inches of washed roofing or pea gravel running from $\frac{3}{8}$ inch to a little smaller, followed by 1 inch of coarse sand. Gravel of the pea size was required to be washed before being placed; other gravel was found sufficiently clean. Filter sand was placed to an average depth of $4\frac{1}{2}$ feet and, according to certain requirements which

were specified, was from about 0.22 to 0.28 millimeter in effective size. (See Plate VI, Fig. 2.)

Materials. The cement used on this work was Atlas Portland cement and was of the usual good quality. The results of the tests, grouped by weeks according to the period of setting, are given in Table No. 22.

The sand and gravel for making the concrete was obtained partly from the excavation, partly from the adjoining hillside, and partly from a nearby bank. It was generally good material with a slight tendency toward fineness and with some clayey material in the gravel. This, as will be pointed out by Mr. Thompson, may have had some slight effect upon the strength of the concrete.

The filter gravel was obtained partly from excavation and partly from a nearby bank on Hancock Street near the place where the filter material was obtained for the first filter. The filter sand was obtained from the same bank, and, to a considerable degree, was obtained without any washing, but simply by screening as it came from the bank. The analyses given in Table No. 23 show the condition of the sand and about what proportion was required to be washed. Table No. 24 also shows the time which it took water to pass through a sample of the sand contained in a standard tin, this being a quick means of determining whether the sand was suitable for filtering purposes. About five times per day a check was made upon general average samples of the whole body, by mechanical analysis. The State Board of Health made check determinations from time to time.

Costs. The canvas of bids for this work is given in Table No. 25, and shows the details of the prices bid by the six different contractors, also giving the engineer's estimate made prior to receiving bids. It is interesting to note that there are three bids which total below the engineer's estimate and three bids which run above this; also that the prices of the lowest bidder are about one half of the highest, with the average of the total costs of about $2 500 higher than the engineer's estimate. The greatest variations occur in the items of cofferdam, excavation, and concrete, and are about the same proportions as the variations in the totals.*

* A copy of the final estimate is given in Table No. 26.

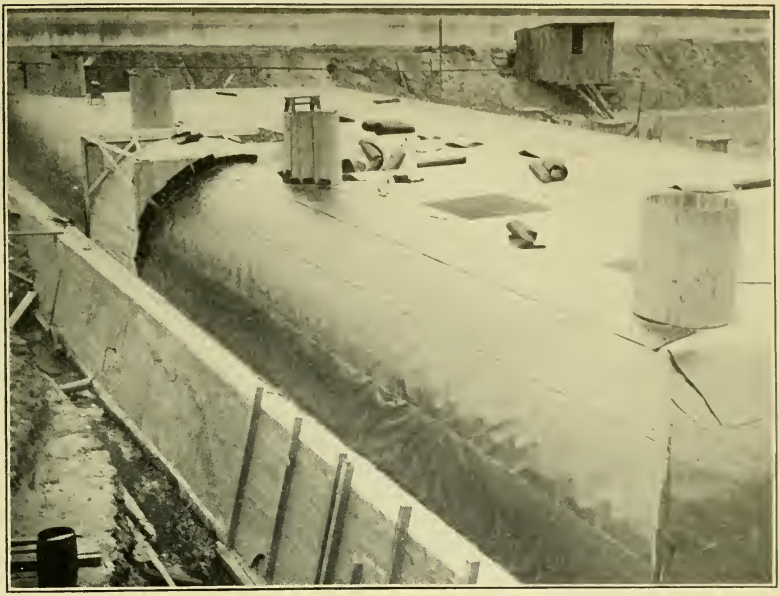


FIG. 1. View of Barrel Arch and Outside Wall, Nov. 1, 1906.

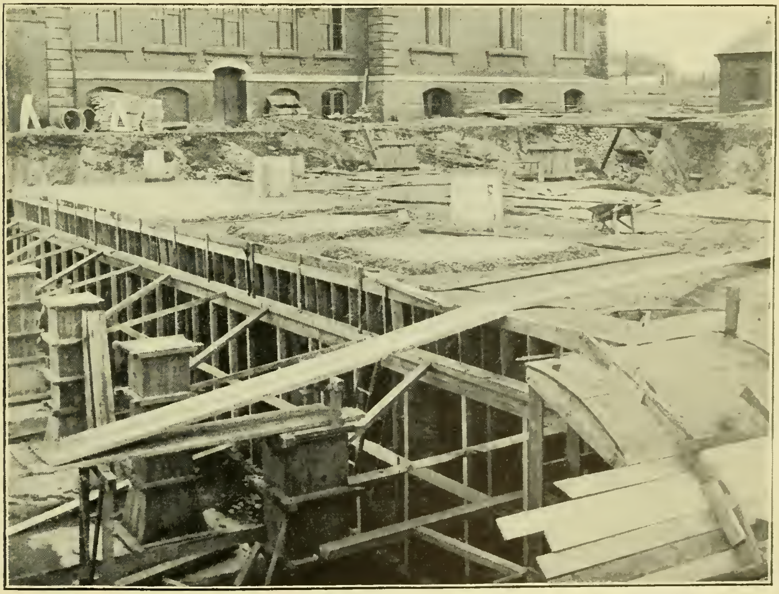


FIG. 2. Forms for Piers and Vaulting, looking Northeast, Nov. 15, 1906.

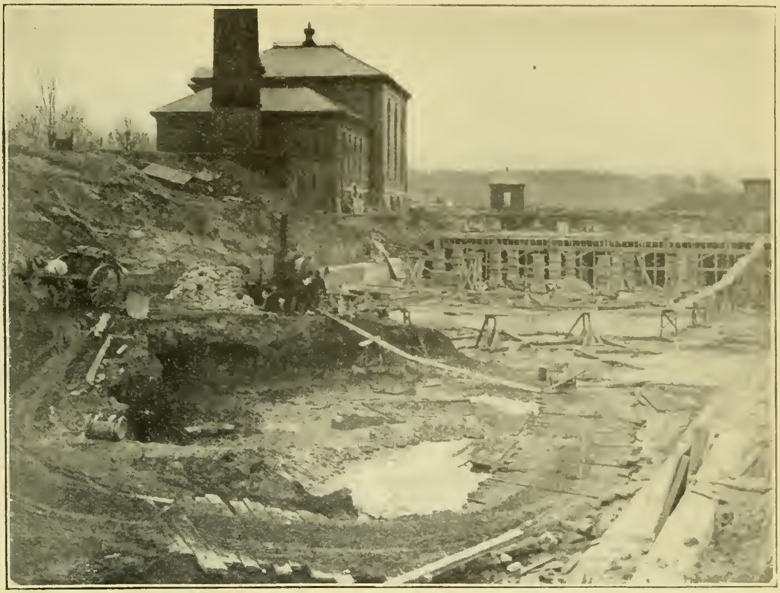


FIG. 1. General View of Construction, looking East, Nov. 1, 1907.

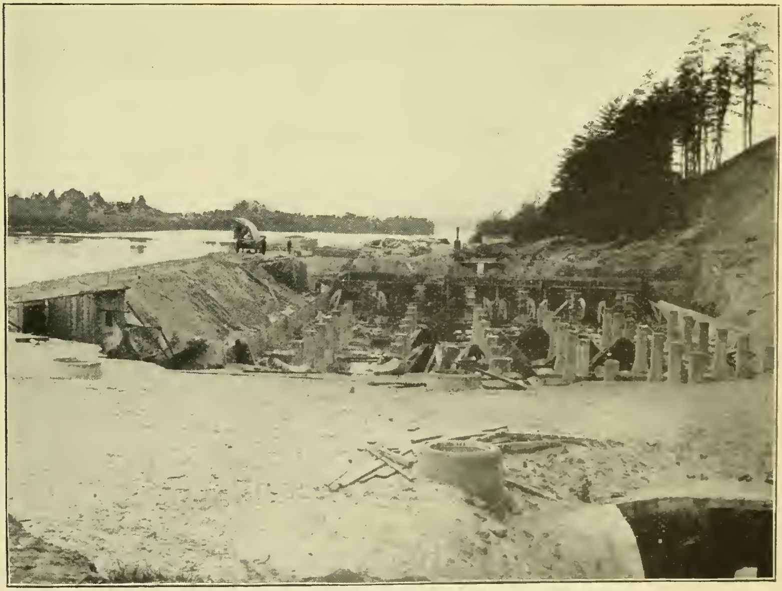


FIG. 2. Piers and Forms for Vaulting, looking West, May 24, 1907.

FIG. 1. Outside Bay of Filter Interior, Aug. 29, 1907.

FIG. 2. Outside Bay of Filter, Sand in Place, showing Distributing Trough, Nov. 4, 1907.

FIG. 1. Main Collector, Laterals and Under-drainage System, Sept. 16, 1907.

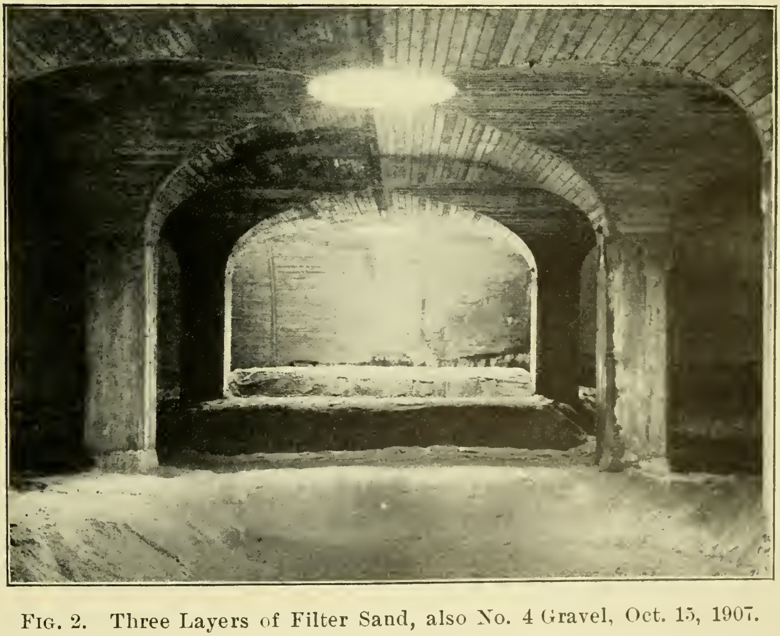


FIG. 2. Three Layers of Filter Sand, also No. 4 Gravel, Oct. 15, 1907.

FIG. 1. Finished Surface of Filter Sand, Nov. 4, 1907.

TABLE No. 22.

Tests of Atlas Cement Used in Lawrence Filter.
FOR WEEK ENDING DATE GIVEN.

Mixed During Week Ending	Per Cent. of Water.	Time in Air, Days.	Time in Water, Days.	Per Cent. of Sand by Weight.	Tensile Strength.	No. of Samples.
One-Day Tests.						
Aug. 11, 1906.	18	0	1	Neat	350	9
Sept. 15, ,,	16	0	1	,,	468	10
,, 22, ,,	16	0	1	,,	561	10
,, 29, ,,	16	0	1	,,	308	5
Oct. 6, ,,	16	0	1	,,	380	15
,, 13, ,,	16	0	1	,,	388	5
,, 20, ,,	16	0	1	,,	362	15
,, 27, ,,	16	0	1	,,	326	5
June 8, 1907.	18	0	1	,,	261	5
,, 15, ,,	21	0	1	,,	234	10
July 20, ,,	20	0	1	,,	283	5
,, 27, ,,	18	0	1	,,	263	5
Average,					364	
Seven-Day Tests.						
Aug. 11, 1906.	18	1	6	Neat	688	6
Sept. 15, ,,	16	1	6	,,	730	5
,, 22, ,,	16	1	6	,,	629	15
,, 29, ,,	16	1	6	,,	823	5
Oct. 6, ,,	16	1	6	,,	790	5
,, 13, ,,	16	1	6	,,	813	10
,, 20, ,,	16	1	6	,,	653	5
,, 27, ,,	16	1	6	,,	738	15
Nov. 17, ,,	17	1	6	,,	745	10
Aug. 11, ,,	24	1	6	300%	274	2
Sept. 22, ,,	24	1	6	300	148	5
June 1, 1907.	18	1	6	Neat	636	5
,, 8, ,,	18	1	6	,,	493	5
July 6, ,,	16	1	6	,,	676	5
,, 13, ,,	22	1	6	,,	516	5
,, 20, ,,	22	1	6	,,	515	5
June 15, ,,	22	1	6	300	222	15
Average,				Neat,	687	
,,				300%,	210	
Twenty-eight Day Tests.						
Aug. 10, 1906.	18	1	27	Neat	868	2
,, 28, ,,	16	1	27	,,	736	5
Oct. 5, ,,	16	1	27	,,	913	5
,, 26, ,,	16	1	27	,,	838	10
,, 28, ,,	16	1	27	,,	749	5
Aug. 10, ,,	24	1	27	300	256	2
Sept. 21, ,,	24	1	27	300	235	5
Oct. 5, ,,	24	1	27	300	167	5
Average,				Neat,	818	
,,				300%,	210	

TABLE No. 23.

MECHANICAL ANALYSES AND WATER TIME TESTS OF FILTER SAND FOR NEW LAWRENCE FILTER, 1907.

Date.	No. of Sample.	Washed or Unwashed.	Water Test. Min.	Water Test. Sec.	M. M. 60 Per Cent.	M. M. 10 Per Cent.	Unif. Coef.
September.							
20........	1	Washed.	..	..	.70	.20	3.5
20........	2	"	..	..	.92	.26	3.5
20........	3	"	..	47	.90	.28	3.2
20........	4	"	1	8	.89	.23	3.8
21........	5	"	..	..	.90	.26	3.4
21........	6	"	..	..	.91	.26	3.5
21........	7	"	..	..	.95	.26	3.6
22........	8	Unwashed.	..	..	.72	.21	3.4
22........	9	"	..	..	.82	.23	3.6
22........	10	"	1	2	1.10	.25	4.4
22........	11	".	1	15	.82	.22	3.7
24........	12	Washed.	..	48	1.00	.26	3.8
24........	13	"	..	58	.92	.26	3.5
24........	14	"	..	..	.92	.24	3.8
24........	15	Unwashed.	1	21	.91	.23	3.9
24........	16	Washed.	1	9	.81	.22	3.6
25........	17	"	..	53	.97	.25	3.8
25........	18	"	1	16	.77	.24	3.2
25........	19	"	1	20	.82	.23	3.5
25........	20	"	..	54	.87	.25	3.4
25........	21	"	1	6	.93	.24	3.8
Average for week....................				40	.88	.24	3.6
26........	22	Washed.	1	20	.71	.23	3.1
26........	23	"	1	14	.97	.25	3.8
26........	24	"	..	52	1.20	.31	3.9
26........	25	"	1	9	.84	.26	3.2
26........	26	"	1	14	.90	.36	3.4
26........	27	"	1	12	1.10	.25	4.4
26........	28	"	1	18	.76	.23	3.3
27........	29	"	1	32	.77	.25	3.1
27........	30	"	1	15	.71	.22	3.2
27........	31	"	1	30	.77	.22	3.5
27........	32	"	1	23	.68	.24	2.8
27........	33	"	1	22	.65	.23	2.8
28........	34	"	1	32	.52	.22	2.3
28........	35	"	1	5	.96	.26	3.7

TABLE No. 23 — *Continued.*

Date.	No. of Sample.	Washed or Unwashed.	Water Test. Min.	Sec.	M. M. 60 Per Cent.	M. M. 10 Per Cent.	Unif. Coef.
September.							
28........	36	Washed	1	27	.77	.23	3.2
28........	37	"	1	35	.52	.21	2.4
28........	38	"	1	25	.81	.25	3.2
28........	39	"	1	30	.82	.22	3.7
28........	40	Unwashed.	1	58	.44	.19	2.3
28........	41	Washed.	1	58	.44	.21	2.1
28........	42	"	1	34	.72	.22	3.2
30........	43	"	1	45	.70	.21	3.3
30........	44	"	1	20	.94	.22	4.2
30........	45	"	1	20	.72	.24	3.0
30........	46	"	1	10	.77	.24	3.2
30........	47	"	1	20	.73	.24	3.0
30.........	48	"	1	18	.72	.24	3.0
30	49	Vein.	..	..	.77	.26	3.0
October.							
1........	50	Washed.	1	25	.84	.24	3.5
1........	51	Unwashed.	1	25	.62	.23	2.7
1........	52	"	1	12	.74	.25	3.0
1........	53	Washed.	1	26	.81	.23	3.5
1........	54	"	1	20	.80	.24	3.3
1........	55	"	1	35	.85	.24	3.5
2........	56	"	1	35	.81	.22	3.6
2........	57	"	1	8	.93	.24	3.8
Average for week...............			1	21	.77	.25	3.1
3........	58	Washed.	1	19	.79	.24	3.2
3........	59	"	1	16	.90	.25	3.6
3........	60	"	1	2	.94	.25	3.6
3........	61	Unwashed.	1	10	.79	.24	3.2
3........	62	"	1	2	.86	.26	3.3
3........	63	"	1	2	.84	.26	3.2
3........	64	"	1	12	.82	.25	3.2
3........	65	Washed.	..	48	1.40	.31	4.5
3........	66	"	1	28	.77	.20	3.8
4........	67	Unwashed.	1	30	.64	.21	3.0
4........	68	"	1	15	.82	.25	3.2
4........	69	"	1	10	.82	.24	3.4
4........	70	"	1	18	.99	.24	4.1
4........	71	"	1	8	1.00	.27	3.3

TABLE No. 23 — *Continued.*

Date.	No. of Sample.	Washed or Unwashed.	Water Test. Min.	Water Test. Sec.	M. M 60 Per Cent.	M. M. 10 Per Cent.	Unif. Coef.
October.							
5........	72	Washed.	..	57	.92	.26	3.5
5........	73	,,	1	5	.83	.24	3.4
5........	74	Unwashed.	..	55	1.00	.27	3.7
5........	75	,,	1	20	1.20	.27	4.4
6........	76	,,	1	27	1.30	.24	5.4
6........	77	,,	1	8	1.20	.25	4.8
7........	78	Washed.	1	18	.91	.24	3.7
7........	79	,,	1	5	.91	.23	3.9
7........	80	,,	..	44	1.50	.27	5.5
7........	81	Unwashed.	1	8	1.40	.26	5.3
9........	82	,,	1	30	1.30	.25	5.2
9........	83	,,	..	55	1.30	.28	4.6
9........	84	,,	1	20	1.30	.26	5.0
Average for week...............			1	12	1.02	.25	4.0
October.							
10........	85	Unwashed.	1	2	1.30	.31	4.1
10........	86	,,	1	16	1.10	.25	4.0
10........	87	,,	1	7	1.50	.31	4.5
11........	88	Washed.		57	1.30	.27	4.8
11........	89	Unwashed.	1	30	.93	.22	4.2
11........	90	,,	1	5	1.10	.23	4.7
12........	91	,,	1	13	.97	.25	3.8
12........	92	,,	1	5	.90	.24	3.6
14........	93	,,	1	2	1.40	.25	5.6
15........	94	,,	..	40	1.00	.31	3.2
Average for week...............			1	6	1.15	.26	4.3
October.							
18........	95	Unwashed.	1	5	1.10	.28	3.9
18........	96	,,	..	57	.94	.28	3.3
19........	97	Bank.	..	..	.90	.25	3.6
19........	98	,,	..	..	1.00	.25	4.0
19........	99	,,	..	..	.83	.22	3.7
20........	100	Washed.	1	34	.74	.22	3.4
20........	101	,,	..	..	.95	.26	3.6
21........	102	,,	1	10	.86	.24	3.5
21........	103	Bank.	..	..	.91	.23	3.9
22........	104	Washed.	..	..	.86	.26	3.3
22........	105	,,	..	..	.89	.26	3.4
22........	106	,,	..	..	.89	.26	3.4
22........	107	Bank.	..	..	.96	.24	4.0
22........	108	,,	..	..	.87	.29	3.0
23........	109	,,	..	..	.80	.23	3.5
23........	110	Washed.	..	..	.92	.26	3.5
23........	111	Bank.	..	..	.81	.22	3.6
23........	112	Washed.	..	..	.91	.26	3.5
Average for week...............			..	..	.90	.25	3.6

TABLE No. 23 — *Continued.*

Date. October.	No. of Sample.	Washed or Unwashed.	Water Test. Min.	Water Test. Sec.	M. M. 60 Per Cent.	M. M. 10 Per Cent.	Unif. Coef.
27........	113	Bank.	1	10	.92	.27	3.4
27........	114	Washed.	..	57	1.00	.27	3.7
28........	115	"	..	55	1.05	.28	3.7
28........	116	"	1	27	.79	.22	3.6
28........	117	"	1	55	.95	.24	3.9
29........	118	"	1	..	.86	.25	3.4
29........	119	"	1	2	1.10	.27	4.0
29........	120	"	..	52	1.00	.27	3.7
29........	121	"	1	16	.90	.23	3.9
29........	122	"	1	17	.87	.23	3.6
29........	123	"	1	10	.88	.25	3.5
29........	124	"	1	32	1.00	.25	4.0
29........	125	"	1	30	1.00	.25	4.0
29........	126	"	1	33	.97	.25	3.8
29........	127	"	1	35	.92	.24	3.8
29........	128	"	2	10	.66	.19	3.4
30........	129	"	1	28	1.00	.25	4.0
30........	130	"	1	22	.96	.25	3.8
30........	131	"	1	42	.79	.23	3.4
30........	132	"	1	41	.93	.24	3.8
30........	133	"	1	39	.82	.23	3.5
30........	134	"	1	26	.77	.21	3.6
30........	135	"	1	44	.89	.25	3.5
30........	136	"	1	29	.89	.24	3.7
31........	137	"	1	16	.89	.24	3.7
31........	138	"	1	12	.91	.24	3.8
31........	139	"	1	40	.76	.23	3.3
31........	140	"	1	20	.86	.24	3.5
31........	141	"	2	7	.79	.22	3.5
31........	142	"	2	19	.76	.21	3.6
31........	143	"	1	42	.82	.23	3.5
31........	144	"	1	26	.82	.23	3.5
31........	145	"	1	22	.94	.26	3.6
31........	146	"	1	25	.98	.26	3.7
31........	147	"	1	52	.77	.21	3.6
31........	148	"	1	40	.95	.26	3.6
31........	149	"	1	51	.87	.23	3.7
31........	150	"	1	25	.83	.23	3.6
31........	151	"	1	42	.84	.22	3.8
31........	152	"	1	33	.95	.25	3.8
31........	153	"	1	40	.92	.24	3.8
31........	154	"	1	47	.91	.25	3.6
31........	155	"	1	33	.84	.22	3.8
31........	156	"	1	40	.82	.22	3.7
31........	157	"	1	37	.87	.23	3.6
31........	158	"	1	40	.84	.23	3.6
31........	159	"	1	23	.97	.24	4.0
31........	160	"	2	11	.71	.21	3.3
Average........................			1	32	.90	.24	3.7

TABLE No. 24.

Water Test of Filter Sand for New Lawrence Filter.

Date.	No. of Samples.	Average Time. Min.	Average Time. Sec.	Minimum Time. Min.	Minimum Time. Sec.	Maximum Time. Min.	Maximum Time. Sec.	No. which were of Washed Sand.
September 20....	10	–	57	–	37	1	47	10
,, 21....	5	–	50	–	46	–	56	5
,, 22....	9	1	13	1	2	1	32	9
,, 24....	9	1	1	–	45	1	26	9
,, 25....	7	1	12	–	58	1	36	7
,, 26....	9	1	11	–	52	1	23	9
Average for week,	8	1	4	–	39	1	27	8
September 27....	10	1	18	–	56	1	32	10
,, 28....	8	1	34	1	7	1	55	8
,, 30....	6	1	21	1	10	1	45	6
October 1....	6	1	28	1	12	1	45	4
,, 2....	20	1	12	–	48	1	47	10
,, 3....	14	1	17	–	55	2	3	2
Average for week,	11	1	22	1	1	1	48	7
October 5....	10	1	13	–	50	1	45	0
,, 6....	26	1	25	1	–	1	52	7
,, 7....	18	1	18	–	42	1	45	7
,, 9....	23	1	18	–	45	1	56	4
,, 10....	47	1	21	–	48	1	58	4
Average for week,	25	1	19		49	1	51	5
October 11....	31	1	19	–	55	1	46	2
,, 12....	32	1	18	–	53	1	45	4
,, 13....	61	1	21	–	47	1	57	61
,, 14....	32	1	21	–	47	1	56	32
,, 15....	27	1	28	–	51	1	50	27
,, 16....	37	1	21	–	53	1	50	37
,, 17....	50	1	27	–	47	3	–	50
Average for week,	39	1	22	–	50	2	1	30
October 18....	42	1	17	–	40	1	50	42
,, 19....	38	1	18	–	40	1	58	38
,, 20....	19	1	29	–	47	2	14	19
,, 21....	31	1	26	–	38	2	50	31
,, 22....	44	1	29	–	34	2	22	44
,, 23....	47	1	25	–	42	2	22	47
,, 24....	49	1	31	–	37	2	28	49
Average for week,	39	1	25	–	39	2	18	39

TABLE No. 24 — *Continued.*

Date.		No. of Samples.	Average Time. Min.	Sec.	Minimum Time. Min.	Sec.	Maximum Time. Min.	Sec.	No. which were of Washed Sand.
October	25....	42	1	34	–	47	2	24	42
,,	26....	58	1	31	–	52	2	19	58
,,	27....	31	1	41	–	44	2	16	31
,,	28....	9	1	42	1	35	1	58	9
,,	29....	10	1	43	1	35	1	57	10
,,	30....	10	1	43	1	35	1	59	10
,,	31....	34	1	29	–	59	1	48	34
November	1....	22	1	31	–	56	2	5	22
,,	2....	40	1	25	–	52	1	46	40
,,	4....	4	1	33	1	24	1	38	4
Av'r'ge last 10 dys.,		26	1	35	1	8	2	1	26

NOTE: Test made by placing 10 cubic inches of sand, closely measured in another tin, into a conical receptacle, having a screen at the base of 14 meshes to the inch. Testing receptacle was 3 inches in diameter at top, 2 inches in diameter at the bottom and 8 inches high. A coarse screen, of 6 meshes to the inch, was placed on top of the sand, water was then filled in the receptacle and the time of passage through the sand was noted. Acceptable filter sand allowed the water to pass through in from one minute to one minute and thirty seconds.

TABLE No. 26.

FINAL ESTIMATE OF CONSTRUCTION OF LAWRENCE FILTER, DECEMBER 1, 1907.

Item No.	Items.	Quantity.	Prices.	Amounts.
1	Cofferdam	Lump.	....	$3 600.00
2	Excavation	,,	....	11 550.00
3	Slope paving	1 210.5 sq. yds.	$2.50	3 026.25
4	Concrete in floors			
5	Concrete in walls	2 974 cu. yds.	5.57	15 562.58
6	Concrete in piers			
7	Concrete in roof			
8	Roof centers	32 305.6 sq. ft.	0.15	4 845.84
9	Cast-iron pipe	19.15 tons.	70.00	1 340.50
10	Cast-iron specials	4.24 tons.	100.00	424.00
11	Valves and appurtenances	Lump.	.....	500.00
12	Regulating and indicating apparatus	Lump.	.....	500.00
13	Structural work	15 304 lbs.	0.04	612.16
14	Tile drainage system	Lump.	.....	850.00
15	Filter gravel	902 cu. yds.	1.00	902.00
16	Filter sand	4 991 cu. yds.	0.60	2 994.60
17	Entrance	Lump.	.....	1 200.00
18	Extra work			1 538.18
	Total..			$49 446.11
	Total cost of filter, including printing, issuing of bonds, and engineering..			$54 331.48

TABLE No. 25.

CANVASS OF BIDS FOR CONSTRUCTION OF LAWRENCE FILTER. RECEIVED MAY 30, 1906.

Item Number.	Item.	Quantities.	Engineer's Estimate.	M. O'Mahoney, Lawrence. (Successful Bidder.)	Coleman Bros., Boston, Mass.	Ward & Coombs, Lowell, Mass., and Dover, N.H.	Cole & Holland, Lawrence.	C. E. Trumbull & Co., Lawrence.	Bruno, Salomond & Petitti, Boston, Mass.
1	Cofferdam, etc.	Lump	$7 500.00	$3 600.00	$3 000.00	$10 052.00	$17 420.00	$7 000.00	$10 000.00
2	Excavation	Lump	14 500.00	11 550.00	15 000.00	16 000.00	21 000.00	33 000.00	27 000.00
3	Slope paving	900 sq. yds.	1.50	2.50	1.50	0.75	0.75	1.00	1.50
4	Concrete in floors	900 cu. yds.	7.50	5.57	6.00	8.00	6.00	6.50	8.00
5	Concrete in walls	900 cu. yds.	8.00	5.57	7.00	7.00	6.00	7.50	9.00
6	Concrete in piers	150 cu. yds.	10.00	5.57	8.00	8.00	6.00	9.00	10.50
7	Concrete in roof	950 cu. yds.	7.00	5.57	8.00	8.00	7.50	8.50	12.00
8	Arch centers	32 000 sq. ft.	0.10	0.15	0.10	0.10	0.13	0.10	0.10
9	Cast-iron pipe	20 tons	70.00	70.00	50.00	40.00	55.00	60.00	50.00
10	Cast-iron specials and flanged pipe	5 tons	100.00	100.00	125.00	80.00	100.00	100.00	80.00
11	Gates, valves, and appurtenances	Lump	500.00	500.00	600.00	400.00	300.00	500.00	500.00
12	Regulating and indicating apparatus	Lump	1 500.00	500.00	1 300.00	1 400.00	250.00	1 500.00	1 000.00
13	Structural work, etc.	11 000 lbs.	0.10	0.04	0.04	0.07	0.035	0.05	0.06
14	Tile drainage system	Lump	1 050.00	850.00	780.00	1 500.00	460.70	600.00	2 000.00
15	Filter gravel	800 cu. yds.	1.50	1.00	2.00	2.00	2.25	1.50	1.50
16	Filter sand	5 000 cu.yds.	1.60	0.60	1.00	1.00	1.00	1.25	1.50
17	Entrance	Lump	600.00	1 200.00	150.00	100.00	300.00	100.00	1 000.00
	Total	....	$64 500.00	$47 593.00	$54 545.00	$64 197.00	$72 175.70	$78 525.00	$85 085.00

The final return of the quantity of filter sand, after settling, was within 9 yards of the estimated quantity.

A detail study of the cost of the filter sand shows that two thirds of the sand was washed and that the remaining third passed examination after screening at the bank. The sand from the general run of the bank gave from $2\frac{1}{2}$ to 4 per cent. finer than 0.13 millimeter, which was the minimum size allowed. After washing, there still remained from $\frac{1}{2}$ to $1\frac{1}{2}$ per cent. of this same fine material. It was thus estimated that about 3 per cent. was lost in washing, which checks very well with the count of the number of loads hauled from the bank.

No accurate data were kept as to the cost of the sand, but some general notes taken may be helpful. It was estimated that the sand was worth 10 cents a yard at the bank, and the cost of the screening, together with the cost of the hauling, added 40 cents. In addition to this there were $6\frac{1}{2}$ cents more for general expenses, including spreading in the filter, making the total cost of the unwashed sand, $56\frac{1}{2}$ cents per cubic yard, delivered in place at the filter. In the same way it was estimated that the cost of the washed sand was $76\frac{1}{2}$ cents delivered in place at the filter. When the shrinkage in the water settlement is taken into account, which amounted to $4\frac{1}{2}$ per cent., or a depth of 0.2 foot, these sums became respectively 59 cents and 80 cents. The bid price was 60 cents.

The cost of the filter sand exhibits in a typical way something about how near the contractor estimated what this work would cost him, and it is probable that upon many of the other items of the contract he made no greater amount of money. Perhaps he even lost. It is unfortunate that public work is frequently let to the lowest bidder because of an erroneous belief or public sentiment that if it is not done, there are ulterior and wrong reasons for doing otherwise. The letting of contracts to the lowest bidder, when he does not receive a sufficient amount of money to warrant his putting capital, equipment, and energy into the job, produces a slow rate of speed, which sometimes causes a municipality to lose in the end, and frequently work is unfortunately and badly delayed. This was the case at Lawrence, where the cost, during the winter of 1906–7, was \$10 000 for water

purchased from other towns, and connections, which money could have been saved if this filter had been completed on time. There is no doubt that with energy, well-considered and well-directed efforts, this work could have been accomplished within the time set for its completion.

DISCUSSION.

Mr. Stephen DeM. Gage.* During the eleven years that I have been connected with the Lawrence Experiment Station, I have followed the work of the Lawrence filter and its effect upon the health and prosperity of the people of that city very carefully, and I have been very much interested in the able résumé of the subject which Mr. Knowles, Mr. Marble, and Mr. Collins have presented this afternoon. The construction of the Lawrence filter marks an important epoch in the history of municipal sanitation in the United States, in that it was the first filter constructed in this country for the express purpose of reducing the death-rate from a specific disease, typhoid fever. It marks also the first practical application of data obtained from the operation of experimental filters with a given water supply to the improvement of that water supply by filtration. That a reduction in typhoid fever would ensue from the introduction of filtered water in Lawrence was accurately predicted by the results obtained with experimental filters at the Lawrence Experiment Station in 1890 and 1891, and this prediction has been more than fulfilled. In addition, a very material reduction has occurred in the total death-rate of the city, a reduction so different in character from that gradual decrease due to increased appreciation of municipal sanitation which has taken place throughout the state of Massachusetts, and following so closely the introduction of filtered water, that it can only be explained by attributing it to the improvement in water supply. In tabulating the results of the national census of 1900, this decrease in the death-rate was made the subject of special inquiry by the chief statistician of the census bureau, who addressed a letter to the local health officials inquiring if some error had not been made in working up the vital statistics of the

* Biologist, Lawrence Experiment Station, Lawrence. Mass.

city which would account for the sudden drop in many of the death-rates after 1893, as he could conceive of no adequate reason for such a marked reduction.

In the accompanying diagram, Fig. 3, I have plotted the death-rates from all causes and from typhoid fever in both Lawrence and Massachusetts for the twenty-five years from 1881 to 1905. A study of the plotted curves reveals that during that period there has been a gradual decrease in both typhoid and in general mortality in Massachusetts. The Lawrence curves are characteris-

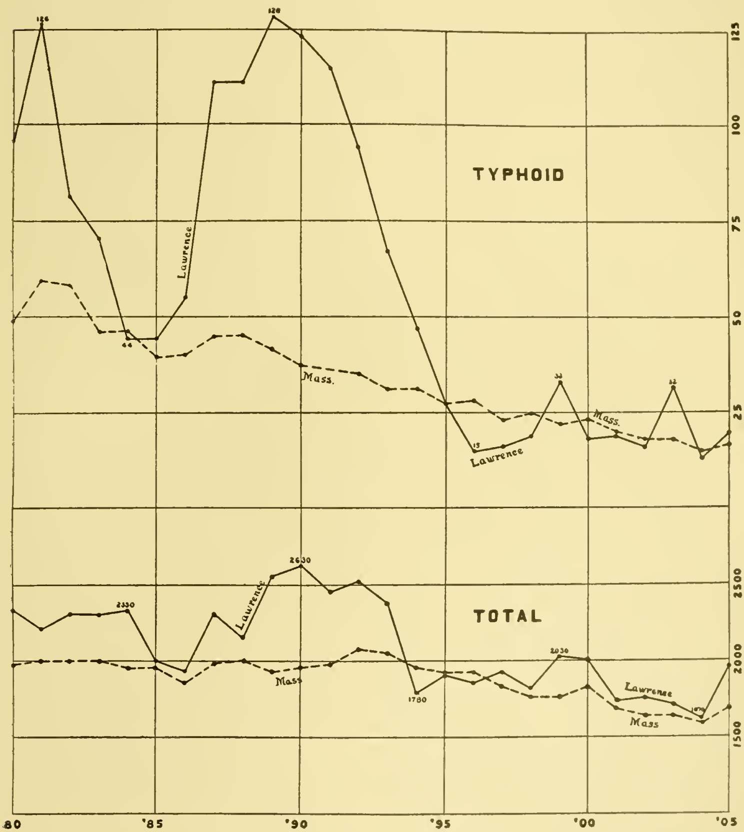


FIG. 3. Comparison of Death Rates in Lawrence and in Massachusetts during Twenty-Five Years.

tically different from the Massachusetts curves. Previous to 1890, the Lawrence curves have an upward inclination, denoting that the total number of deaths, and especially the deaths from typhoid fever, were increasing faster than the population. In 1891 and 1892 the people were warned of the dadger of drinking the city water and many adopted the precaution of boiling the water or began using spring water, and the curves assume a downward tendency from that time, which tendency was made permanent by the introduction of filtered water in 1893.

It will be noted that the typhoid death-rates for Lawrence after 1895 were lower than those for the whole state except in three years, and the cause of these few high points must be sought for outside of the filtered water supply, as Mr. Collins has explained.

It is usually considered that the material prosperity of any municipality is measured in part at least by the healthfulness of its population. Let us consider what effect the introduction of filtered water has had upon the prosperity of the city of Lawrence. It is usually accepted that the loss of a human life represents a loss in the earning capacity of a community of about $5 000. For every person who dies from typhoid fever there are ten who recover but whose illness has entailed a loss to the community of at least $100, or a loss of $1 000 for each death, so that the drain on the community is actually about $6 000 for each death from typhoid fever. During the ten-year period from 1881 to 1890, when unfiltered water was being used, the mean annual death-rate from typhoid fever was 90 deaths per 100 000. During the ten years from 1896 to 1905, when filtered water was in use, the mean yearly death-rate from typhoid fever was 20 per 100 000, an average annual saving of 70 lives per 100 000 by the decrease in this one disease. With an average population of 61 600 during these ten years, this means an actual annual saving of 43.12 lives represented by $6 000 each, or a net gain to the community of $258 700 per year. The average cost of filtration, including interest on the cost of the filter during the same period, was only about $12 000 per year, and the total cost of water-works maintenance, including interest and depreciation, was only about $110 000 per year. In other words, the introduction of filtered water into the city of Lawrence may be said to have caused a yearly saving to the com-

munity of about twenty times the cost of filtration and of more than twice the entire cost of supplying water. A similar computation might be based on the reduction in the total death-rate, when the annual saving would be found to amount to more than one and one-third million dollars, but the decrease in typhoid fever alone has yielded an ample return on the money invested in the filtration plant and fully warrants such extensions and improvements in the plant as are necessary to keep pace with a rapidly increasing population.

Mr. M. F. Collins. When Mr. Gage called your attention to the curved lines, showing the death-rate from typhoid fever in Lawrence before and after the building of the filter, the high points for the years 1903 and 1907 were especially noted. I feel that the increase in typhoid fever cases in the years 1903 and 1907 calls for some explanation. In 1903 the Lower Pacific Mill had 43 cases reported. The local Board of Health called the attention of the state board of health to the conditions existing at the above mill, and the state board delegated one of their corps of assistants to investigate and locate the cause if possible. It was found that the check valve which was placed between the city mains and their mill supply was leaking. The mill authorities were notified to place another check valve within a few feet of the other, which was done, and no further complaints were received from that source.

During the year 1907, in the Washington Mills, from January 28, to March 1, there were 48 cases of typhoid fever and 7 deaths from this mill alone, thus greatly increasing the number of cases for the year. After several of these cases had been reported, the local Board of Health investigated the condition of affairs there and insisted on the mill authorities providing better facilities for supplying pure drinking water for their help. After these improvements had been made this epidemic ceased and there has been no unusual number of cases there since. The following table gives the number of cases and deaths from typhoid fever and the tributary causes as far as they could be ascertained at the time.

TABLE No. 27.

Typhoid Fever for 1907.

Months.	Cases.	Imported.	Contracted.	Canal Water.*	Spring Water.†	Total.	Deaths.	Imported.	Contracted.	Canal Water.*	Spring Water.†	Total.
January...........	15	3		8	1	15	0					0
February..........	51		3	39	4	51	6			6		6
March	5	1	1	1	1	5	3			2		3
April..............	9		1	4	1	9	1					1
May..............	5			3		5	2			1		2
June..............	3			1		3	1					1
July..............	6			3		6	2					2
August...........	7	1		4		7	0					0
September........	8	3		2	1	8	4	2				4
October...........	6			5	1	6	1			1		1
November.........	7			2	1	7	1					1
December.........	7	1	1	4		7	0					0
Total‡..........	129	9	6	76	10	129	21	2	0	10	0	21

* Canal Water. Persons employed in mills where canal water is used and who may have had access to that water.

† Spring Water. Persons who have used spring water exclusively.

‡ From January 28 to March 1 there were 48 cases and 7 deaths among the employees of one mill in this city, the Washington Mills.

INVESTIGATION OF COLLAPSE OF FILTER ROOF DURING CONSTRUCTION AT LAWRENCE, MASS.

BY SANFORD E. THOMPSON, CONSULTING ENGINEER, NEWTON HIGHLANDS, MASS.

The acquaintance of the writer with the Lawrence filters began towards the latter part of May, 1907, when, at the request of Mr. Knowles, he made an examination and report upon the collapse of a portion of the roof.

The investigation involved an examination of the concrete and the materials composing it, besides a general inspection of the condition of the filter after the collapse.

The concrete was laid in three divisions: First, the floor with its inverted groined arches; next, the columns, which were dowelled to the floor by two pieces of 1-inch iron pipe, projecting about 8 inches up into the column; and finally the roof of groined arches resting upon the columns and supported temporarily upon centering constructed in the usual manner for this type of work.

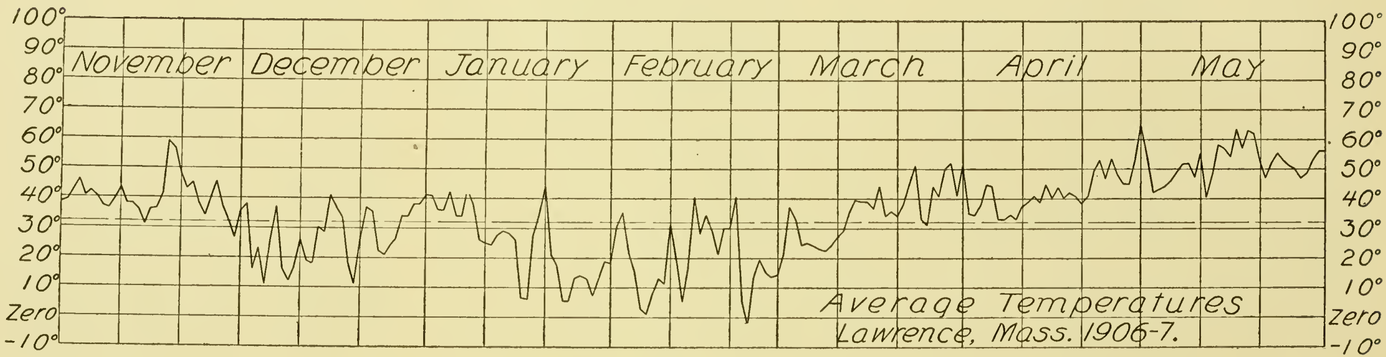
Various causes delayed the construction, and it was not until the 1st of November, 1906, that any concrete was laid upon the roof. At this time a length of 8½ bays of floor, out of a total length for the entire reservoir of 21 bays, and 8 rows of piers, had been placed.

Of the roof, 7½ bays were laid before the closing down for the winter, as follows:

November 2, 1906 — 2½ bays laid.
November 9, 1906 — 1 bay laid (from 2½ to 3½).
November 23, 1906 — 2 bays laid (from 3½ to 4½).
December 17, 1906 — 2 bays laid (from 5½ to 7½).

The forms for the last two bays (5½ to 7½) were up and ready for concrete on the last day of November, but they waited until the middle of December to get a temperature as high as 28° F. in the morning with prospect of a good day.

As many of you will remember, the fall and winter of 1906–7 were unusually cold, and as this had an important bearing upon the failure, Fig. 1, a curve of the temperature from November 1,



November
December
January
February
March
April
May
Average Temperatures
Lawrence, Mass. 1906-7.
100°
90°
80°
70°
60°
50°
40°
30°
20°
10°
Zero
-10°

FIG. 1.

1906, to June 1, 1907, has been prepared. It is seen that the temperature dropped below freezing the last of November, and there was scarcely any real thawing weather until well into March. At the time the last two bays of concrete were laid, December 17, the average temperature was just above freezing, but that night it dropped below freezing and the next day but one reached 6° above zero.

As soon as the concrete was laid in the arches, they were covered with straw to a depth of 6 inches, and later about 2½ feet of sand and gravel were placed on top of the straw, the last two arches being filled upon about two or three weeks after they were laid.

The contract requires, with reference to work in cold weather, General Clauses, Section 23:

"In case any unforeseen contingencies arise which will prevent the work being completed by November 15, 1906, and it becomes necessary to do work in the winter weather, no embankment shall be made and no concrete shall be mixed, nor placed, nor masonry laid, nor any other operation performed, likely to be interfered with by cold, during any of the months of December, January, February and March, and thereafter until the frost is out of the ground, unless permission be obtained from the engineer. If, however, the engineer is of the opinion that any operation can be satisfactorily performed during these months, he may give the contractor a special written permit, which permit shall define the work and the conditions under which such work may be done and such conditions shall be faithfully followed.

"The contractor shall be responsible for all defects in the work done during these months which may arise from the action of the elements, notwithstanding such permit and additional precautions taken. He shall make good such work, and shall make good any work destroyed or damaged by the frost, even though built at any other season of the year."

No permit had been given to the contractor to continue work in December.

A diagram of the easterly end of the filter where the collapse occurred is shown in Fig. 2. To the dotted line this represents a length of about 110 feet out of a total length of reservoir of 313 feet.

The general construction of the forms and the method of placing the concrete is shown in Plate I, Fig. 1. The only lateral bracing, it

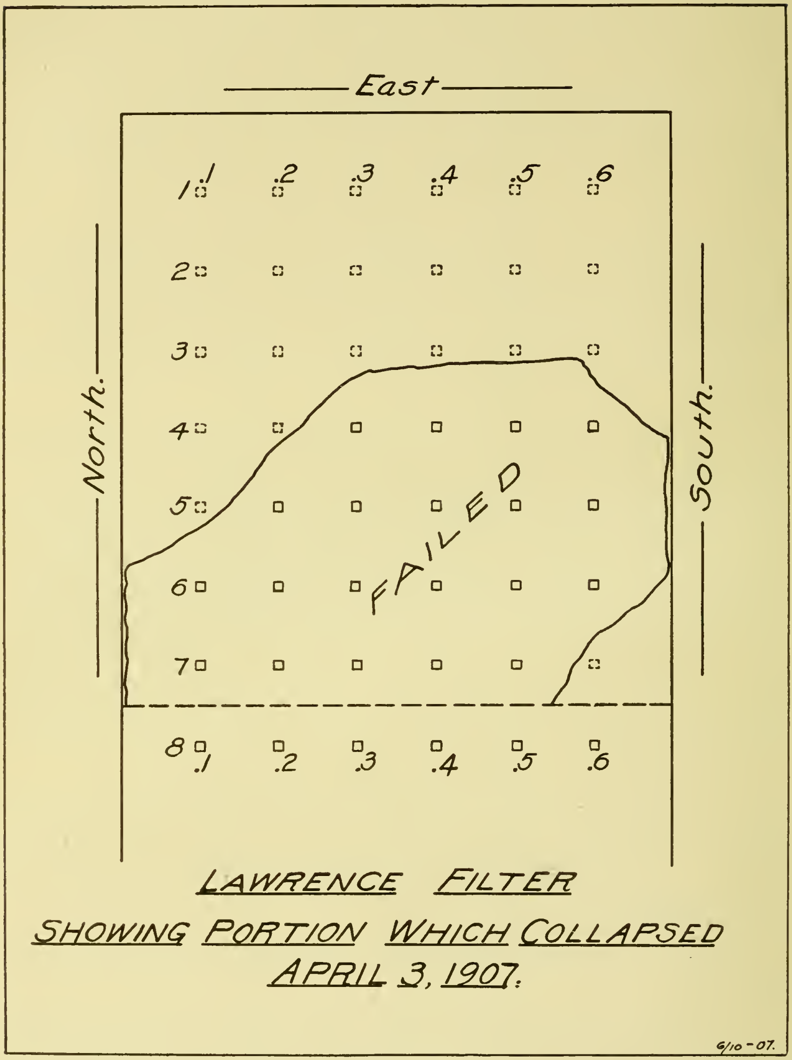


FIG. 2.

will be noticed, consisted of light wooden braces, nearly horizontal, resting against the piers at the height of the second clamp from the top. The only resistance to lateral thrust was therefore that due

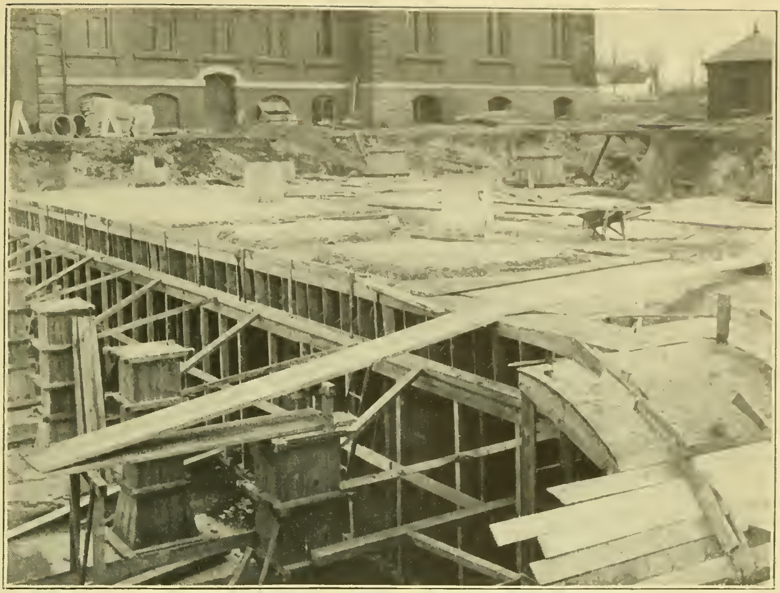


FIG. 1. Forms for Roof of Lawrence Filter.

FIG. 2. After the Fall of the Roof.

to the weight of the pier and the adhesion of two short lengths of round rods in the bottom of the pier.

During the winter the centering had been removed from the first three bays of the roof, leaving a length of 4½ bays with the centering in place.

On the day previous to the fall the carpenters began to remove the centers from these last bays, so that at night all the centering was down except the half centers between the seventh and eighth rows of columns, the full centers in the next bay, and the four north arches between the fifth and sixth rows. The foreman carpenter told me that when he came on the next morning, April 3, he noted that a 4 × 8 inch horizontal piece in one of the half centers was twisted, but he did not attach any importance to it. The men began to work on the north arches of bay 5-6 when a cracking was heard, and they all got out from under. The break appeared to start about the center of the reservoir, — that is, about halfway between the two sides, — and the whole roof seemed to go down at once. Fortunately, the men were warned in time and no one was injured.

The visit of the writer to the filter was not until May 23, but the condition was substantially the same then as on April 3, the date of the fall, scarcely any clearing having been done.

The general condition of the reservoir a few hours after the fall of the roof is shown in Plate I, Fig. 2, and Plate II, Fig. 1. All the columns in the last row, line 8, against which the end of the centering was braced, were standing; but one of these columns at about the center of the reservoir and where the break was said to start is slightly canted. In the next or seventh row, four piers were standing, but all of them tipped, including the pier in the row under the southwest arch. The columns in the other rows were nearly all broken. Pier 8.3, which is shown as slightly canted at the time of the fall, was afterward pried over, and the cleavage of the base from the floor was smooth, as one would expect of a joint between concrete laid on two different days. The two steel dowels which projected into the pier had pulled out, leaving clean surfaces.

A view looking northeast after cleaning up the loose concrete and forms is given in Plate II, Fig. 2.

A closer view of the third row columns which were still standing showed that several of them were tipped toward the west, and a crack had opened at the top, that is, at the springing line of the arch, about $\frac{1}{2}$ inch wide. Three were out of plumb from 1 to $2\frac{1}{2}$ inches, and these were also cracked at the base as well as the top. In the portion of the roof remaining, cracks were noticed, mostly along the crown of the arch.

EXAMINATION OF THE CONCRETE.

The concrete at the time of the fall was so soft and crumbly that it could be readily pulled to pieces. At the time of my visit it was fairly hard, evidently having hardened very much since the failure. The stones, however, pulled from the concrete more easily than they should have done in first-class concrete, indicating that even at this time the concrete was not very strong. Concrete from the upper surface of the roof, especially in the thick masses above the columns, was noticeably weaker even at date of my visit than the concrete next to the centers. At the date of reading this paper, ten months after the accident, the samples referred to above are sound and hard.

EFFECT OF MANURE.

In certain places pieces from the top surface of the roof were much discolored. Examination showed that the concrete had been in contact with manure contained in the straw, while other neighboring portions of the roof surface which were covered with clean straw were of normal color. The discolored portions, the color extending to a depth of about 1 inch, were softer than the rest of the concrete and readily flaked when rubbed between the fingers. Although this did not extend deep enough to be in itself responsible for the failure of the roof, the condition was such as to show very conclusively that manure is a bad thing to place in contact with green concrete, and that when straw covering is employed, it should be free from manure.

In this connection the writer may say that he recently had occasion to examine a barn floor of concrete and also several concrete drains in this floor which had been in use for a number of years in continual contact with manure, and found the surface absolutely

FIG. 1. After the Fall of the Roof.

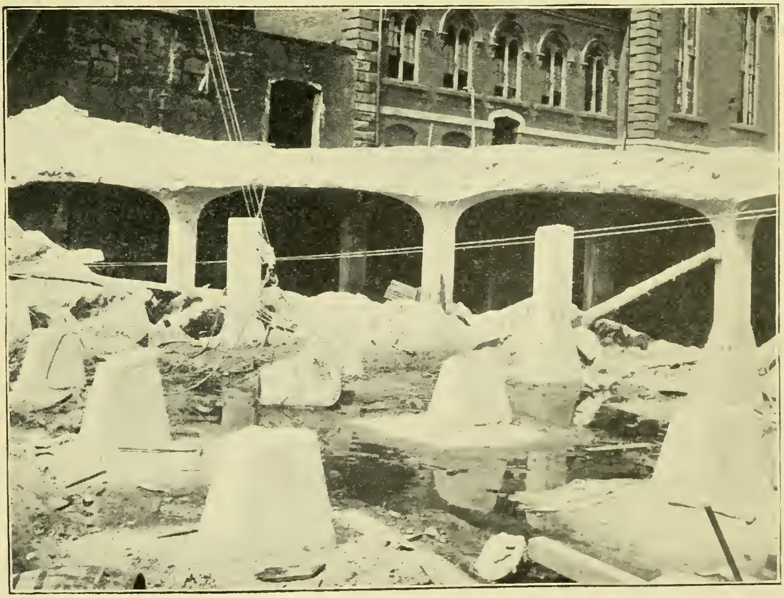


FIG. 2. After Most of the Debris had been Removed.

hard and perfect. A tank containing manure was also in similarly good condition. The conclusion, therefore, may be drawn that manure is likely to injure green concrete, while not affecting well made concrete after it has set and hardened.

SAND AND GRAVEL.

The sand and gravel used for the concrete were from a pile which had been excavated from the site of the filter. This material was screened into gravel for the coarse aggregate or ballast, and sand. Four samples of the sand were taken, and two samples of the screened gravel. Examination of the sand and of its analyses shows that it is all of medium quality, containing a somewhat excessive percentage of dirt for maximum strength, but none too much for water-tightness. Examination of the analyses of the gravel shows a large percentage of material under $\frac{1}{4}$ inch, the sample with the least fine material screening 20 per cent. below $\frac{1}{4}$ inch, although the contract specifies (Section 28), that, " all particles smaller than one quarter ($\frac{1}{4}$) inch shall be screened out." The specifications require proportions 1: 3: 5. If 20 per cent. of the gravel is below $\frac{1}{4}$ inch, and therefore sand, the proportions are actually 1: 4: 4, thus giving a concrete greatly inferior in density and strength to that required by the specifications. Many of the gravel stones were covered with a coating of very fine clayey sand, which after drying in the laboratory and screening by hand for five minutes did not entirely come off. Tests by Mr. Howard A. Carson (recorded in the Seventh Annual Report of the Boston Transit Commission, 1901, p. 39) show one third greater strength for concrete made from washed gravel than similar concrete made with gravel coated with a thin film of dirt. The excess of fine material tends to make the concrete not only weaker but slower in setting and hardening.

The contract specifies (Section 28) that the gravel " shall be washed if necessary to render it sufficiently clean," but this was not done.

EFFECT OF LOW TEMPERATURE.

The temperature records taken at Lawrence during the winter of 1906 indicate only a very few days at which the temperature was above freezing.

As already stated, the last arches were not laid until December 17. On the following day, as shown by the curve in Fig. 1, the temperature dropped below freezing, and there were only a few days when the temperature was above freezing before the earth covering was placed. The covering naturally tended to equalize the temperature, so that the concrete would not then have the full benefit of the occasional warmer days during the winter and early spring.

It is common knowledge that continued cold prevents concrete from reaching its normal growth in strength. Tests at the Watertown Arsenal * and elsewhere, the results of which are readily available, have brought out this point clearly, showing that if the temperature is maintained below freezing the cement after several months has only a fraction, — on the average we may say about $\frac{1}{3}$, — the strength that it would have reached with a temperature of 70° F. Even a temperature as high as 39° F. retards the hardening so that the strength may not be more than two thirds of what would be attained at 70° F. As soon as any of the specimens were removed from the cold and placed in a warmer temperature the hardening was accelerated, and a strength nearly normal was soon reached.

At Lawrence the effect was similar, the concrete rapidly gaining strength after exposure to the warmer atmosphere in April and May.

CENTERING.

The contract specifies, Section 58:

"The contractor shall notify the engineers when he proposes to strike centers, but no centers shall be struck opposite the outside walls until the embankment has been completed to the springing line, and no other centers shall be struck until at least five (5) rows of vaulting beyond have been completed."

The five rows of centering which are required to remain in place at all times are evidently for the purpose of allowing the concrete to set and also to take up the thrust of the arches due to temperature or unequal loading. The contractor evidently assumed that

* Taylor & Thompson's "Concrete, Plain and Reinforced," p. 412.

the provision was only for the purpose of giving time for the concrete to set, for he was removing the forms with no diagonals left in place, except a few braces placed against a row of piers, which had only their own weight to keep them in an upright position.

Without attempting to analyze the thrust of the arches, it is evident that if the half center at the end had been loaded with earth to the full height, it would have balanced the pressure from the next arch, so that the line of thrust from all the arches would have come directly into the piers. However, in filling a roof like this, the earth cannot be carried square to the edge, but slopes off, probably in such a case as this at a slope of 1 to 2, or 1 to 3, so that there must be a thrust from the arches beyond it if they are unsupported.

The assumption that the thrust was a factor in the fall is strengthened by the facts that (1) one half of the bay between column rows 3 and 4 was laid as late as November 23, thus having only twelve days more to set with the temperature slightly above freezing than the outer bays, and yet this bay suffered the removal of the forms without apparent damage; (2) the bay between column rows 5 and 6, half of which was laid on the final date, December 17, 1906, did not fall on the day when the forms were removed from the first portion of it, although unreinforced concrete falls quickly with but slight warning; (3) warning of failure was given by cracking of the centers and apparently commenced in about the middle of the reservoir, near pier 8.3, which was tipped from the thrust of the diagonal braces against it.

CAUSES OF FAILURE.

The data presented enable us to reach definite conclusions in regard to the causes which contributed to the failure.

The design of the groined arch roof is one universally endorsed, being similar to that adopted with satisfaction in many other filters built from the year 1895 to the present time. It is consequently impossible to attribute the failure of the Lawrence filter roof in any way whatsoever to the design.

The causes of the failure therefore must lie in the construction. After removal of the forms supporting the roof the fall appears to

have been due to a combination of two causes, neither of which alone would probably have occasioned the accident.

(1) The thrust of the arches.

(2) The weak condition of the concrete because of

(*a*) Low temperature, which retarded the hardening;

(*b*) Improper screening of gravel, producing an excess of sand which tends to make concrete slow in hardening;

(*c*) Dirty gravel, reducing the strength of the concrete.

All of these causes were probably contributory to the fall. The subsequent hardening of the concrete indicates that no trouble could have ensued if the forms had remained for a longer time and until more arches had been placed.

REPAIRS.

The wrecked portion of the roof and the broken piers were removed, and replaced by a new structure built to the same design. The arches which remained standing, but which were cracked and had separated along the crown, and the piers supporting them, which were slightly tipped, were thrown back into place by jacking up the arches vertically, and at the same time jacking them horizontally to bring them into place, close the cracks, and plumb the piers.

PRODUCER GAS PLANTS.

BY HENRY CROWTHER,* PHILADELPHIA, PA.

[*A discussion on paper by Harry L. Thomas, read January 8, 1908.*]

We have installed gas-producer plants up to 800 and 1 000 horse-power. We are doing more of this in the West than in New England. We have installed for the American Locomotive Works, at their Richmond shops, a 500 horse-power gas-producer plant which is developing 160 000 000 foot-pounds per 100 pounds of coal. For the Pennsylvania Railroad, near Wilmington, we have installed two 100 horse-power gas-producer plants driving 100 horse-power Westinghouse engines. At Poughkeepsie, N. Y., and at New Orleans, we have installations of gas-producer plants. The duty developed has ranged from 120 to 140 and 160 million per 100 pounds of coal.

Mr. Thomas hit the nail on the head when he said, in summing up, that, after all, experience is necessary in running these plants. This is no trick after a man has had some experience, but it is impossible to expect a steam engineer, or a steam boiler fireman, to take hold of one of these plants and run it offhand. There are certain precautions to be observed, the principal of which are, — that your coal should be of as uniform a character as possible, and it should not exceed a certain per cent. of hydrogen, say about 18 to 20 per cent., because if you exceed that you get back firing. This was the cause of Mr. Thomas' trouble; he struck there a coal with a high per cent. of sulphur, which, if persisted with, would have pitted the engine so badly in the course of a few weeks that he would have had to renew the parts. These are points which come with practical experience.

The economies of producer gas plants are so manifest that, in the West particularly, where they seem to have taken these things up more extensively, they are being rapidly adopted, and up to large units. We haven't put in anything over 1 000 or 1 200

* With R. D. Wood & Co.

horse-power yet, but they are building now for the United States Steel Corporation gas engines up to 4 000 horse-power; they operate either on natural gas or blast-furnace gas, but they could be operated on producer-gas with by-product recovery. This, however, is only possible in large units, 3 000 or 4 000 horse-power and upwards. The whole thing sums itself up when you can show an economy of from three to five times what a steam engine will give you. When you can develop, as has been done, 20 horse-power for one cent an hour per horse-power, with coal at $1.50 a ton, the fact is forced upon you that the gas-producer with the gas engine is going to be, and is already, a very active competitor of the steam engine, and is bound ultimately to force it out.

The chief engineer of the Pennsylvania Railroad told me last year that in the opinion of their engineering department the steam turbine was only an intermediate step between the steam engine and the gas engine. It must be remembered, if you please, that steam boiler men and steam engineers are a development of a century of progress, and they know these things by rote. If you will give the same amount of attention to the operation of your gas engine and gas-producer as you have given to your steam engine and steam boiler, there will be no difficulty in their operation. And while, as one gentleman very aptly said, we had better bear the ills we have rather than flee to those we know not of, yet, at the same time, those latter ills are more apparent than real, if you get right down to it.

In Poughkeepsie the saving effected by the gas-producer plant over the old steam plant paid for the cost of the plant (about $4 000) inside of twenty-two months. They saved at the rate of about $185 or $200 per month, in comparison with what they had been paying before with a steam engine and steam boiler.

The President. I should like to ask Mr. Crowther what is really the best type of fuel to use in these plants.

Mr. Crowther. Anthracite coal, undoubtedly. Anthracite gives you a clean gas; the B.t.u. runs about 140, and you have no trouble with cleaning.

The report of the United States Geological Survey, which can be had from the government, shows that at the government testing

station at Forest Park, St. Louis, they tested out lignite, peat, wood, straw, coke, charcoal, — everything, in fact, that could be burned, — and yet they got back to the fact that anthracite coal is the best fuel for all purposes. But bituminous coal (if you don't get it too slack), or even run of mine, with automatic cleaners, is all right, although in that case, when you have to put tar cleaners in, it involves additional cost, of course. Therefore anthracite remains the best. In other words, the best fuel is that which is free from the hydrocarbons — a high percentage of hydrocarbons.

Mr. Thomas. Mr. President, if I may be excused for speaking about one other thing which is brought to my attention, which I omitted in the paper, the matter of feeding the generator: perhaps you all understood clearly how our generator is fed, — we clean the fire and fill the generator once in three hours. Under good practice that is as often as it is necessary to do it. Sometimes, if the coal is running rather poor, we have to clean it every two hours and a half, but we usually clean it every three hours. And whereas we were advised in the first place to sift the ashes and put them back, our experience has taught us there is no economy in doing that, for while it may cut down the record of the coal for a day's run, it will make so much ash and dirt in the fire that the additional coal used the next day will make up what you did not use that day. So we simply take that and put it on one side, and we contemplate shaking it out and burning it under our steam plant to get rid of it.

Mr. Crowther. With proper handling a gas-producer can be started with the engine in about an hour to an hour and a half, and when the fire has been simply let stand it only requires a few minutes over night.

At our works at Camden we have gas-producers coupled to different makes of engines, and our men, naturally having had much experience, have no difficulty in starting promptly. If it took a day to start a fire in order to get gas from a producer to an engine, the company making them had better go out of business. The statement quoted by Mr. Thomas is far-fetched, and the man who made it did not understand his business. That is the only charitable remark that can be made about that.

Mr. Farnum. Mr. President, I would like to ask how many

men it takes to run this plant, and if there is any economy in that direction.

Mr. Thomas. In the matter of attendants, our plant is exactly the same as the steam plant, — one man takes care of the plant at both places; it takes but one man.

Mr. Cassell. I would like to inquire if either of the gentlemen can give us the relative cost as between the establishment of a steam plant and this gas plant they are talking about, in an approximate manner.

Mr. Crowther. Yes. The cost of a gas-producer plant, fully equipped with producer, gas engine, washers, scrubbers, and everything of that sort, as compared with a steam plant, is very nearly a stand-off. There are probably two or three dollars more you might figure on per horse-power, but the increased cost of the gas engine is more than offset by the increased cost of the boiler house, stack, foundations, and that sort of thing, as compared with a gas-producer house. I am speaking of the ordinary sizes, built of corrugated iron, or something like that.

While the cost of the installation of the gas-producer is probably 2 or 3 per cent. more than that of a steam plant, perhaps the cost of maintenance and repairs, on the other hand, is largely in favor of the gas-producer.

Speaking on that very point which Mr. Thomas cited, of getting a gas-producer started, the Erie Railroad at Jersey City has had now for nine years, I think, Westinghouse gas engines running with R. D. Wood producers, and in one of those producers for nine years the fire has never been out; it has never, therefore, required relining with fire brick. So that you can very readily understand the great economy of the maintenance and repair charges. But, roughly, it is about a stand-off; there is very little difference, in large installations.

PROCEEDINGS.

March Meeting.

Hotel Brunswick,
Boston, March 11, 1908.

President Alfred E. Martin in the chair.

The following members and guests were present:

Members.

S. A. Agnew, M. N. Baker, C. H. Baldwin, A. F. Ballou, G. W. Batchelder, F. E. Bisbee, George Bowers, E. C. Brooks, G. A. P. Bucknam, W. L. Butcher, C. E. Childs, J. H. Child, W. F. Codd, R. C. P. Coggeshall, M. F. Collins, W. R. Conard, J. H. Cook, C. E. Davis, A. W. Dean, M. J. Doyle, E. D. Eldredge, B. R. Felton, A. N. French, C. W. Gilbert, A. S. Glover, F. W. Gow, F. H. Gunther, E. L. Grimes, F. E. Hall, J. C. Hammond, Jr., T. G. Hazard, Jr., B. B. Hodgman, H. G. Holden, J. W. Kay, E. W. Kent, Willard Kent, Patrick Kieran, G. A. King, J. J. Kirkpatrick, E. E. Lochridge, N. A. McMillen, D. E. Makepeace, A. E. Martin, John Mayo, H. A. Miller, William Naylor, F. L. Northrop, O. E. Parks, H. W. Sanderson, P. R. Sanders, E. M. Shedd, G. H. Snell, G. A. Soper, G. A. Stacy, W. F. Sullivan, R. J. Thomas, W. H. Thomas, D. N. Tower, W. H. Vaughn, C. K. Walker, F. B. Wilkins, C.-E. A. Winslow, G. E. Winslow, E. T. Wiswall. — 65.

Honorary Member.

Wm. T. Sedgwick. — 1.

Associates.

Allen & Reed, Inc., by Henry W. Littlefield; Anderson Coupling Company, by F. A. Leavitt; Ashton Valve Company, by C. W. Houghton and Charles L. Bucknam; The Fairbanks Company, by F. E. Smith; Hersey Manufacturing Company, by Albert S. Glover and Walter A. Hersey; International Steam Pump Company, by Samuel Harrison; Jenkins Bros., by H. F. Fiske; Charles Millar & Son Company, by Charles F. Glavin; Lead Lined Iron Pipe Company, by Thomas E. Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould; H. Mueller Manufacturing Company, by George A. Caldwell; National Meter Company, by Charles H. Baldwin and J. G. Lufkin; National Water Main Cleaning Company, by B. B. Hodgman; Neptune Meter Company, by H. H. Kinsey; Norwood Engineering Company, by H. W. Hosford; Pittsburg Meter Company, by F. L. Northrop; Platt Iron Works Company, by F. H. Hayes; Rensselaer Manufacturing Company, by F. S. Bates and C. L. Brown;

A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by E. M. Shedd; Union Water Meter Company, by F. E. Hall and E. M. Barnard; United States Cast Iron Pipe and Foundry Company, by F. W. Nevins; Water Works Equipment Company, by W. H. Van Winkle, Jr.; R. D. Wood & Co., by W. F. Woodburn. — 29.

Guests.

F. W. Dinwiddie, Gardner, Mass.; George F. Merrill, superintendent water works, Greenfield, Mass.; Charles N. Oakes, Westfield, Mass.; James G. Hill, Lowell, Mass.; John F. Stark, president Pennichuck Water Works, Nashua, N. H.; W. W. Trowbridge, West Newton, Mass.; L. H. Cornfel and W. Burmbain, Boston; Charles F. Chase, Providence, R. I.; William E. Smith and Lettice R. Washburn, New Bedford, Mass.; A. E. Blackmer, Plymouth, Mass.; Thomas G. O'Connell, Wakefield, Mass. — 13.

[Names counted twice — 6.]

The Secretary read the following names of applicants for active membership:

Arthur E. Blackmer, Plymouth, Mass., superintendent of Water Works; George F. Merrill, Greenfield, Mass., superintendent of Water Works; William E. Smith, New Bedford, Mass., member of Water Board; William H. Pitman, New Bedford, Mass., member of Water Board; Lettice R. Washburn, New Bedford, Mass., member of Water Board.

On motion of Mr. Eglee, the Secretary was directed to cast the ballot of the Association in favor of the admission of the applicants whose names had been read, and he having done so, they were declared elected members.

The Secretary read the following communication:

Philadelphia, February 19, 1908.

New England Water Works Association,
715 Tremont Temple, Boston, Mass.:

Gentlemen,— Believing that the salvation of the remnant of our forests is one of the most pressing duties of the nation, I respectfully urge your careful and favorable consideration of House Bill No. 10 457, "For Acquiring National Forests in the Southern Appalachian Mountains and White Mountains," and the adoption at an early meeting of resolutions urging this matter upon the Committee of Agriculture, Hon. Charles F. Scott, chairman, Washington, D. C.

Yours truly,

John C. Trautwine, Jr.

The President. The communication has been before the Executive Committee and has been referred to this meeting by action of the committee. I think Mr. Baker has something to say on the subject.

Mr. M. N. Baker. When this matter was brought up in the Executive Committee there was some discussion on the broader subject of the conservation of the natural resources of the country, which subject includes not only the preservation of forests, but the conservation and the development and utilization of the water resources of the country, and also a study of such other natural resources as our coal supplies. As probably all those here know, there was appointed some months ago by President Roosevelt a commission styled "The Inland Water-Ways Commission," to take up, primarily, an investigation of and to map out a scheme for the development of the navigation of the country; but the President very wisely made his instructions to this commission broader, and the commission in its recent report, in accordance with the detailed request of the President, entered upon a consideration of the broad questions of the conservation of the natural resources of the country, giving particular attention to the water resources.

It is unnecessary to elaborate upon this point, but I wish to bring to your attention the fact that the national engineering societies have taken up this matter of the conservation of the natural resources of the country, and that also there is to be held in May, at the call of President Roosevelt, a convention of the governors of all the states of the Union at Washington just about the time of the meeting of the American Water Works Association. And at this conference of the governors with the President there will be a number of papers read, and discussions, and perhaps the formulation of some policy in regard to the conservation and future development of the natural resources of the country.

Now as water-works men and as engineers, the members of this Association are, of course, primarily interested in all that pertains to the water resources of the country, their conservation in quantity and in purity. The bearing of the forestry question upon the water resources of the country is so evident to all that nothing

need be said upon that subject. The Executive Committee of this Association decided to recommend to the Association the appointment of a committee on the conservation and development and utilization of the natural water resources of the country, that committee to consist of five members, appointed by the chair, and to have power to confer with and to coöperate with like committees from the engineering societies or any other associations that might take similar action. Inasmuch as we have a very full program for this afternoon, I will not take up any more of your time, but I think it is evident to all that it is very important that this Association get in line with others and appoint a committee to take this matter into consideration and to coöperate with others.

I might say just one thing more, which will be of particular interest to the members of this body who are not informed of the fact, and that is that there is now under consideration by the United States Geological Survey and by the United States Bureau of the Census, a census of the water-powers of the United States. Such a census, you will remember, was taken in 1880, but it has not been revised since that time, and meanwhile there have been very great developments and very many changes, and it is possible, although not certain, that another census of the water-power will be taken. It will be becoming for this Association, and for its individual members, to do what can be done to further the taking of such a census.

Mr. Sullivan. I move that the report of the Executive Committee be accepted and adopted, and that a committee of five members be appointed by the President to look after and keep track of legislation and other matters pertaining to the conservation, development, and utilization of the natural resources of the country.

The motion was adopted, and the President subsequently appointed the following-named gentlemen as the committee: M. N. Baker, William T. Sedgwick, Leonard Metcalf, Allen Hazen, and George A. Soper.

Mr. Eglee. Would it not seem desirable, Mr. President, that an expression of opinion from this Association should be made at the present time and forwarded as requested? Every one here

is certainly interested in the preservation of the water-power and in the conservation of water supplies, and it would seem as though a resolution passed here, or framed by the committee to be passed before the close of this session, might be of value. The appointment of a committee of five to follow this legislation is, of course, a very good thing, but, as I understand it, we do not meet again until June, which will be after the adjournment of Congress. I would make the suggestion, not as a motion, that a committee of two might be appointed at the present time to draft a resolution, which might possibly be endorsed by this session of the Association, and forwarded to the proper official.

Mr. Sullivan. This matter came up in the Executive Committee about half past twelve to-day, and after talking it over we thought the time was too short in which to draft any resolutions, and it was the intention of the Executive Committee to have this sub-committee appointed who would take care of that matter.

Mr. Eglee. Would Mr. Sullivan permit an amendment to his motion to the effect that the committee appointed by the President should be empowered to draft a suitable resolution and forward it to the proper officers previous to the adjournment of the present session of Congress?

Mr. Sullivan. I certainly would accept that as another motion, but my motion has already gone through.

The President. I understand Mr. Eglee makes this as a suggestion, but I will put it as a motion, that the committee be instructed to prepare such a resolution.

The motion was adopted, and the President announced the committee would govern itself accordingly.

The first paper of the afternoon was read by George A. Soper, Ph.D., consulting sanitary engineer, New York, on "The Typhoid Fever Epidemic at Watertown, N. Y., in 1904." The paper was discussed by Prof. William T. Sedgwick and Prof. C.-E. A. Winslow.

Mr. E. L. Grimes, chief engineer, Bureau of Water Supply, Troy, N. Y., gave a description of the "Troy Water Works Extension."

Adjourned.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, March 11, 1908, at 11.30 A.M.

Present: President Alfred E. Martin, and George A. Stacy, M. N. Baker, Robert J. Thomas, George W. Batchelder, D. N. Tower, George A. King, Michael F. Collins, William F. Sullivan, and Willard Kent.

Five applications were received and recommended for membership, viz.:

William H. Pitman, member Water Board, New Bedford, Mass.; William E. Smith, member Water Board, New Bedford, Mass.; Lettice R. Washburn, member Water Board, New Bedford, Mass.; Arthur E. Blackmer, superintendent Water Works, Plymouth, Mass.; George F. Merrill, superintendent Water Works, Greenfield, Mass.

Messrs. George A. King and D. N. Tower, members of the Committee on the June Outing, presented a detailed report (appended hereto) of the proposed arrangements for same, and on motion of Mr. M. N. Baker the report was accepted and the committee continued. The same committee was by vote authorized to procure a photograph of surviving charter members of the Association on the occasion of the June meeting.

The report of Editor Sherman with reference to a revision of the prices charged for back numbers of the JOURNAL of the Association wasreceived, accepted, and, on motion of Mr. M. F. Collins, it was voted that the recommendations of Mr. Sherman be adopted and that the prices named in his report be and hereby are established. This report is appended to these minutes.

A communication from Mr. J. C. Trautwine, Jr., with reference to forest reserves was received, and, after discussion, on motion of Mr. George A. Stacy, it was voted that the Executive Committee recommend to the Association the appointment of a committee to represent this Association in behalf of the movement to con-

serve the natural resources of the country. Mr. M. N. Baker was delegated to present the subject to the Association.

The subject of the September convention was discussed, but no action taken.

Adjourned.

Attest: WILLARD KENT, *Secretary*.

REPORT OF SUB-COMMITTEE ON JUNE OUTING, 1908.

TAUNTON, MASS., February 29, 1908.

The sub-committee on the proposed outing to Plymouth presents the following report:

The boat from Boston to Plymouth will begin making its daily trips on Wednesday, June 17, and the boat is always crowded on that date. The schedule time for leaving Boston is 10 A.M., and reaching Plymouth at 12.45 P.M.; on returning, leave Plymouth at 3.30 P.M., and reach Boston at 6.15 P.M. The regular fare is $1.00 round trip and 75 cents one way. The management would give us a special rate of 75 cents round trip and 50 cents one way. A lunch counter is provided on boat, and undoubtedly some provision could be made for a luncheon for the whole party.

The New York, New Haven & Hartford Railroad now have a train leaving Boston at 8.43 A.M., via Cohasset, and due at Plymouth at 10.45 A.M., and one leaving Plymouth for Boston via Whitman at 5.56 P.M., and due in Boston at 7.17. Undoubtedly there will be trains at about these hours in June and probably more trains than are now scheduled. A party of one hundred and fifty could be carried in two special coaches on regular trains, but if numbers are considerably in excess of one hundred and fifty, a special train would be necessary.

The one-way fare is 75 cents, but for parties traveling together on specified train the following round-trip prices are made:

50–74	$1.20
75–99	1.13
100–149	1.05
150–199	.98
200	.90

Mr. Blackmer advises dining at Hotel Pilgrim, which is about three miles east of the town at the "Head of the Beach." Dinners could be served at prices running from 75 cents to $1.50 per plate, the price to include electric car ride in special cars from the center of the town. The hotel will probably not open before the middle of June.

Single admission to Pilgrim Hall is 25 cents; in lots of one hundred, 10 cents each, but the one hundred must actually go into the hall. A price of 20 cents each for seventy-five has been made occasionally and could probably be obtained if desired.

The committee visited Plymouth and conferred with Mr. Blackmer, the superintendent of the water works, and in view of his desires and the information given above, we make the following

RECOMMENDATIONS:

That the Association make an all-rail trip to Plymouth on the fourth Wednesday of June (the 24th), leaving Boston at about 8.43 A.M., and going by way of Cohasset, and returning by way of Whitman at about 5.56, to reach Boston about 7.17.

That on the arrival in Plymouth it assemble at the Armory, which is about three minutes' walk from the railroad station, to receive a welcome to the town.

That at about 11 o'clock opportunity be given to visit the following places: Pilgrim Hall, nearly across the street from the Armory; the water-works shop on Howland Street, about three minutes' walk from the Armory, where 18-inch cement pipe will be in process of manufacture; the Rock, monument, and such other places as members may desire to visit; that at 12.45 special electric cars be taken at the Armory for the ride to Hotel Pilgrim for dinner; that on the return from the beach those who desire take the barges, provided by the town authorities, at Town Square and visit the work of laying the 18-inch cement main which is to be laid between Little South Pond, the source of supply, and the pumping station. This work will probably be in progress about two miles south of the town; members who desire to make this trip to notify Secretary before leaving Armory in morning.

There are always plenty of carriages to be hired for 25 cents per passenger for visiting different points of interest in town.

The cost of the trip should not exceed \$2.25, based on an attendance of one hundred.

We base our estimate on the following figures:

Railroad fare	\$1.05
Dinner	1.00
Admission Pilgrim Hall,	.10
Printing, tickets, etc.	.10
	\$2.25

Respectfully submitted,

(Signed) GEORGE A. KING,
D. N. TOWER,
Sub-Committee.

Report of the Editor on Prices for Back Numbers of the "Journal."

Boston, February 26, 1908.

Mr. A. E. Martin,
President N. E. Water Works Association,
Springfield, Mass.:

My dear Mr. Martin, — In accordance with the understanding at the last meeting of the Executive Committee when we discussed the matter of price of back numbers of the Journal, I send you the following memorandum and recommendation for presentation at the March meeting, since, unfortunately, I shall be in the West at that time and unable to attend the meeting.

Some years ago we established, by vote of the Executive Committee, a series of premium prices on back numbers of the Journal, by which the price of each copy was increased by 15 cents for each year previous to a certain date. This, of course, makes some of the old numbers very high priced, although, as a matter of fact, we have as many of some of the earlier numbers on hand as we have of some of the comparatively recent ones. A couple of years ago it became necessary to give away quite a number of surplus copies of the Journal in order to clear our shelves. At that time, however, we took pains to retain at least twenty-five copies of all the issues of which we had as many as twenty-five to start with.

We now have on hand five or less copies of only four issues, viz.: No. 4, Volume 1, of which the present price is $2.85; No. 2, Volume 2, the price of which is $2.70; No. 4 of Volume 10, price $1.50; No. 4 of Volume 11; price $1.35. On the present schedule of prices the price of a complete set of the Journal to 1907, inclusive, is $125.50.

I now feel that the effect of the present schedule of prices is, to a large extent, to prevent sales, and as each new issue of the Journal makes an addition to our stock and requires additional storage room, I am inclined to feel that it would be wise to fix a price at which we could move the old issues more rapidly. I also feel that we should fix a price for a whole set at which we could more easily place them in public libraries or libraries of scientific schools.

There have been up to date twenty-one complete volumes of the Journal and two issues of Transactions, or twenty-three annual volumes, one of which covers a year and a half and contains six numbers of the Journal (Volume 15).

I recommend that for all sales of an entire set or of early volumes of the Journal required to make up a set for libraries or for individuals, we make a price of $3.00 per volume (except for Volume

15, which contains six numbers, and for which the price should be $4.50), making $70.50 for a full set up to and including 1907; that for single copies of the JOURNAL of which we have more than five copies on hand the price be $1.00 each, and where we have five or less copies, the price be $2.00, irrespective of the date of issue. Also that where we have not more than five copies of an issue on hand, complete volumes containing the issue be sold only by the single number *except* in case of selling a more or less complete set at one time.

Respectfully submitted,

CHARLES W. SHERMAN, *Editor.*

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XXII. September, 1908. No 3.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

THE SUB-AQUEOUS PIPE AND ELECTRIC CABLE WAY AT GLOUCESTER, MASS.

BY HERMAN W. SPOONER, CIVIL ENGINEER, GLOUCESTER, MASS.

[*Read September 13, 1906.*]

Gloucester is a city by the sea, situated, with the exception of one ward, upon an island between Massachusetts and Ipswich bays, being bounded by them, together with the Squam River and canal. Of course you have heard it said that Gloucester is a part of and located upon "Cape Ann." This section of Massachusetts was a cape, years ago, before it was cut off from the mainland by the construction of the canal, that the skippers of the fishing fleet might lay a more direct course to the Grand Banks. Hence, after the canal was opened connecting the river and harbor, the cape became an island, upon which there was no opportunity to procure a supply of water sufficient to meet the steadily increasing demand.

It will be readily understood that the water mains, — the leading supply mains, — must pass under the water of canal or river at a sufficient depth below low water to cause no interference to navigation. When the plant was built, in 1884, the single supply main was laid just below the bottom of the canal, and it served its purpose until it became advisable to dredge and widen to accommodate craft at all tides, as the bed of the old canal was at the level of low-water mark, allowing no navigation even for small boats during periods of low tide.

On account of this change in width and depth, it became necessary to lower the gas and water mains to a depth of at least 19 feet below high-water mark.

Because of the nature of the ground in the vicinity of the canal, the close proximity to the only avenue by which entrance is gained to the city proper, and the waters of the harbor, it was decided that an attempt to dredge or open cut a trench to the required depth and lay twin mains therein was inadvisable. Therefore a location for vertical shafts and a connecting horizontal tunnel was considered, it being desired to avoid such locations as would cause damage to land owners, hindrance to public travel along Western Avenue, and excessive construction cost. It was decided, therefore, to make borings along a proposed line of construction southerly from Western Avenue, and wholly within lands owned and controlled by the city.

The Harbor and Land Commissioners decided that all pipes or mains should be placed at such a depth below low-water mark as to afford ample opportunity to dredge to a depth of at least 10 feet below this mark, of which only about 6 feet is to be attempted at present.

The test wells or borings were made to a depth of 50 feet below the surface of the floor of the present bridge, and in several instances about 50 feet below the bed of the canal, which is practically equal in level with low-water mark; samples of the materials encountered were procured at different levels, most of which indicated coarse gravel, sand and boulders, but no clay. As borings made north of the bridge for the Harbor and Land Commissioners indicated similar materials, and as it was evident that no clay in any amount was to be found, the final location was established on the southerly side of the avenue within the park. In 1904 plans were prepared, approved by the Water Board and the Harbor and Land Commissioners, including an alternate design, the latter being radically different from the first in all parts, and requiring the pneumatic method of construction throughout. A pamphlet covering "Notice to and Information for Bidders, Bid, Contract, Specifications and Bond" was prepared by the writer, examined and approved by the Board and the city solicitor, and forwarded to such parties as applied.

The bids were advertised in the local and contracting papers, and copies of the pamphlet delivered to fourteen applicants, eight of whom called to examine the plans and view the vicinity of the

proposed work. The samples of the materials taken from the test wells or borings were exhibited and the plans examined, and nearly all applicants decided from the location and nature of the ground through which the work was to be constructed that they would not care to bid.

One bid to do the work was filled out in the required form and filed, together with the required deposit, by Charles R. Gow and John E. Palmer, operating under the firm name of Gow & Palmer, of Boston, Mass.

The bid covering the alternate design, which will be described hereinafter, was considered by the Water Board at length. This bid covered the construction of the entire work, the price named being two hundred and fifteen dollars ($215) per horizontal linear foot for a tunnel to measure, when completed, 130 feet between the centers of the vertical shafts.

The contract and plans required that the contractors construct two circular vertical masonry shafts, interior diameter 11 feet, one on either side of the canal, surrounded to within a few feet of the surface by steel cylinders. The methods of construction were left to the discretion of the contractor, unless objection was made thereto by the writer, and it was assumed that the constructors would place the cylinders in position in a timbered square-sheathed excavation, line them with masonry of the required thickness, and then excavate from the interior, allowing the lined cylinders to settle. A tunnel 9 feet in interior diameter, having a brick wall 1 foot in thickness and incased within a cylinder consisting of steel plates, was to be constructed between these vertical shafts. After the construction of the shafts and tunnel, the contractor was required to place or imbed in concrete in the bottom of the tunnel six lines of vitrified six multiple duct extending along the entire length of the bottom of the tunnel; two lines of cast-iron pipe 20 inches in interior diameter were to be placed above the concrete in which the ducts were to be imbedded, together with a 12-inch main to convey illuminating gas, all of which were to be supported upon brick piers and extended upward through the shafts to a point about 4½ feet below the natural surface. The vertical shafts were to be divided by brick walls 8 inches in thickness into three compartments, the larger portion to be utilized

for the water and gas mains, the other part to be subdivided into two parts or quarters to accommodate high and low-tension wires or cables; both shafts were to be covered with concrete floors, entrance to be made through cast-iron manholes. After considering the bid at length, it was decided to modify the plans that the cost might be reduced, and ring timber or a cylinder of pine 6 inches in thickness to take the place of the steel plates surrounding the brick walls of the tunnel was proposed by the party presenting the bid. This alteration in the original cross-section was drafted by the writer, submitted to the bidder for consideration, and in reply a bid of twenty-six thousand dollars ($26 000) was received to complete the work in accordance with the revised plans and specifications, equivalent to two hundred dollars ($200) per horizontal linear foot.

The Water Board then awarded the contract to Messrs. Gow & Palmer. The first excavation in connection with the actual performance of the contract was made on April 4, 1905, in Marine Park, at the site of the easterly shaft. The steel cylinders, 13 feet in diameter and more than 12 feet high, together with a shorter section of special construction for use as a shoe or bottom piece, arrived by lighter on April 15 and were landed in the park, together with a hoisting engine, derrick, pumps, and other apparatus.

A circular excavation was made for the shaft, sheathed with matched plank 2 inches in thickness, the sheathing being supported by rings of 4-inch channel iron, leaving an opening in the clear of 13 feet 9 inches in which to operate. At a depth of 10 feet boulders were encountered in the coarse gravel, which were removed after blasting; water immediately began to enter the excavation in small volume and was removed by a 3-inch pulsometer pump.

At a depth of 18 feet a decided change was noted in the material, fine dead sand being found, and a decided increase in the quantity of water was evident.

On April 14, when a depth of 19 feet had been reached, the shoe-piece of the cylinder, having a special reinforced cutting edge upon which the masonry lining wall was to be constructed, was placed in position within the sheathing, and a second section of the cylinder was then adjusted, the eye (or portion which was to

be cut out later when the shaft was completely lowered, and through which the tunnel was to be started) centered, and preparation made to place the concrete lining. Fine screened sand was placed between the sheathing and the cylinder to fill the void and act as a guide, which later appeared to be an error, causing great loss of time and expense to the contractor.

While the sheathing was being placed for use as a form to support the concrete lining of the easterly shaft, an excavation was commenced on the westerly side of the canal at the site of the west shaft, in which many large boulders were found and removed after blasting, and from which the cables of the Postal Telegraph Company were removed. This opening was made in the same manner as the easterly excavation; the materials encountered at the several levels were almost identical with those found upon the east side of the canal.

The interior of the cylinder in the east shaft was treated with a three-ply coating of waterproofing, the steel receiving a coat of tar, and tarred paper being applied thereto, and this operation was continued until the desired amount had been placed.

Forms of dressed $1\frac{7}{8}$-inch plank were erected, supported within by rings of double angle-iron, allowing for the placing of concrete 1 foot in thickness inside the waterproofed cylinders. The following mixture of concrete was required and placed: To each 380 pounds of dry Portland cement there was added 5 cubic feet of fine and 11 cubic feet of coarse crushed stone, and 4 cubic feet of clean, sharp bank sand, the whole being mixed very wet.

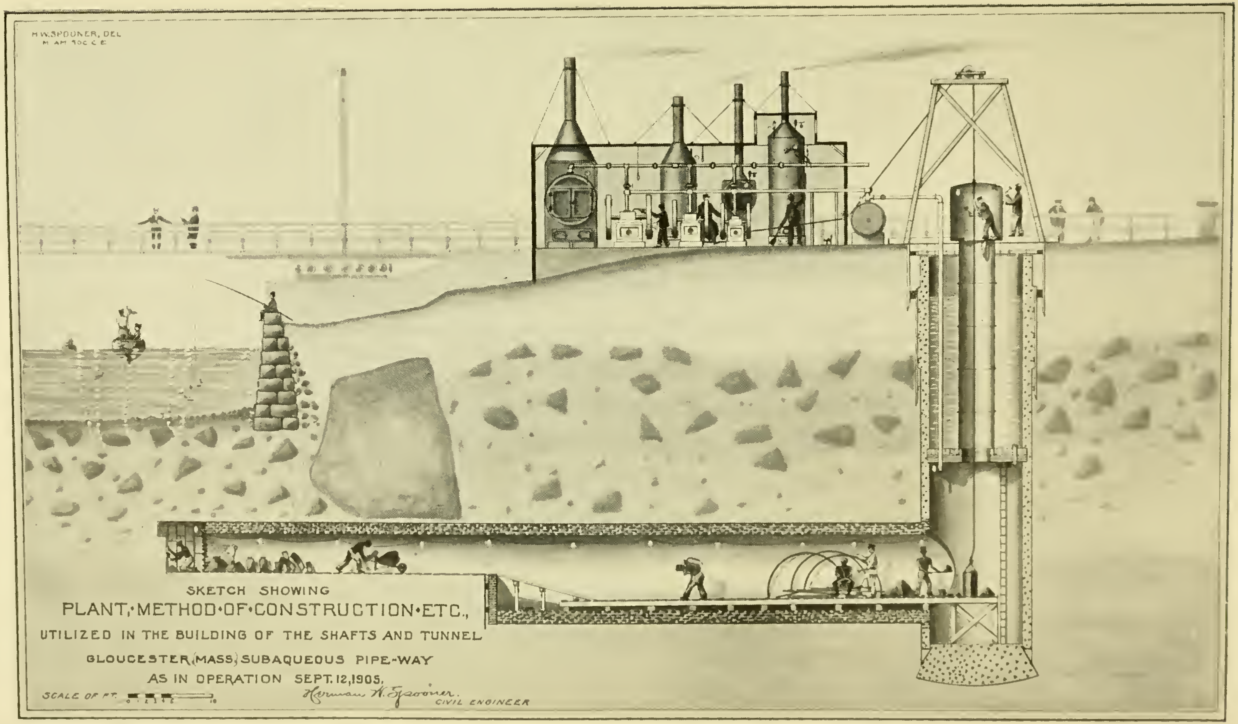
All concrete, and all mortar used in brickwork, was mixed by hand and made with Atlas Portland cement, which passed all of the required tests which are given hereunder.

The double angle-iron rings supporting the forms were set 3 feet apart and were replaced by wooden block rings after the concrete had attained a sufficient degree of hardness. Hooked bolts were set in the concrete as the lining walls were erected, to which stagings may be attached inside the cable chambers.

When several vertical feet of the concrete lining walls had been placed, it was noted that the entire cylinder had settled about 6 inches into the gravel, the cutting edge resting upon a boulder which was found to be under the easterly edge. After this boulder

had been partially removed by blasting, the structure again settled about 3 inches. It was found that the boulder was of large size, and after continued small blasts, small amounts of powder being used on account of the close proximity of the cutting edge, the cylinder slipped past this obstruction and reached a depth of about 21 feet by easy stages.

At this time (April 24) the structure was going downward at the rate of about 20 inches in eleven hours and was becoming gradually out of plumb. The lowest portion of the edge was then blocked and the high side weighted with all available material, but no progress was made, the cylinder having a decided tendency to remain stationary. Another section of steel cylinder was attached to the loaded walls and lined with concrete, the structure being at this time about 6 inches out of level in the width. In this position the cylinder continued to settle slowly notwithstanding the efforts made to guide it to a level or plumb position. It was noted that the fine screened sand which had been placed between the sheathing and the cylinder shifted continually, causing the movable structure to be jammed far to one side, and on account of the shape of the excavation (round) and the impossibility of moving the sand guide at will, the space being too small, it was found to be impracticable to right the cylinder. The volume of water entering the excavation rapidly increased, and as the tide turned, the laborers were obliged to leave the bottom on account of the absence of pumps of sufficient capacity. At this time two 3-inch pulsometer pumps, assisted by a large single-cylinder Emerson pump, were in continuous operation, the depth of the excavation being about 25 feet below the surface of the park and about 5 feet below the low-water mark in Gloucester harbor. It was the intention of the contractor to complete the work without the use of compressed air, treating the ground through which the work was to be built with cement grout, this method being less expensive and having been used to advantage in other and similar work. Here, however, it was found that the nature of the gravel was such that the ground waters at all times moved freely through the ground, so that there was no opportunity at any time to leave grout in place for a sufficient period to allow of its attaining the initial set. Therefore, on May 2, the contractor decided to resort



PLANT AND METHOD OF CONSTRUCTION.

to the use of the pneumatic method of construction. At this time the bottom or cutting edge of the cylinder was about 7 feet below low-water mark, it being necessary to lower the structure about 20 feet further before the required depth was reached. During the next two days the cylinder was worried down to a bed consisting of very coarse, hard gravel and isolated boulders to a depth of 28 feet below the surface of the park.

A recess was cut in the concrete lining to receive the wooden deck which was to support the compressed air tube and lock, and work in the east shaft was abandoned until the apparatus, air compressor, additional boilers, receivers, etc., could be assembled.

The cylinders to be placed within the excavation on the west side of the canal were rolled across the drawbridge and placed in correct order inside the sheathing with the aid of shears, power being furnished from the plant on the east side of the canal. Before being placed in position, six skids or guides consisting of timber 4 by 6 inches in size were affixed by lag screws to the sheathing, being notched at each ring of channel-iron, this pattern of a guide being used in place of the screened sand used in the east shaft. The inside of this cylinder was treated in the same manner as was the one in the opposite shaft and the walls constructed of concrete, an air deck, 18 inches in thickness, being built into the walls as the work progressed. The materials encountered in excavating were nearly identical with those found in the east side except that strata of gravel mixed with iron through which the water entered freely were passed through.

The pumping apparatus was moved to the west shaft and an attempt made to work this cylinder to a greater depth than was reached in the east shaft, but when a level had been reached which was within a fraction of an inch of the level of the bottom of the first shaft, the contractor was forced to abandon operations and wait for the application of compressed air.

While work was being carried forward on the westerly side of the canal, a small compresser with a receiver had been installed near the derrick on the east side of the canal, and on May 27 the air-lock and tubing especially designed and built for this work arrived and were ready, together with the head-house, and in operation, four days thereafter. Previous to this time there had

been very little continuous work, and as when using the pneumatic method there is a continuous expense to maintain a dry excavation, two shifts were organized. The day shift was in charge of the foreman, Mr. Charles B. Lewis, the other, or night shift, being placed in charge of Mr. Russell. Each shift worked eleven hours and consisted of foreman, stationary engineer, fireman, locktenders, miners, tenders, and muckers, generally eleven men being employed during each shift. The men employed upon this work were of the first rank in their several vocations, exercising great care in the performance of the duties assigned to them, and on this account, if for no other reason, the writer is pleased to be able to state that there were no men injured during the execution of this contract, and the final result is entirely satisfactory.

The air compressor was in operation thereafter continually until the work was nearly completed. All materials were removed, and all materials required in construction were transferred, through the air-lock, thus increasing the cost of construction nearly fourfold.

The cylinder was bound in such a manner that although the gravel was excavated from beneath the cylinder to a depth of 3 feet and additional weight was added in the form of water on the deck and piles of brick upon the rim, it did not drop until all the air-pressure had been removed and the earth at the sides of the cylinder commenced to heave inward. This passage of gravel or "heave" from around the cylinder and about the sheathing down and into the void excavated and into which it was desired to drop the structure caused trouble throughout the entire lowering of this shaft, also until the tunnel was completed about 10 feet from the side or eye. Often after working for an entire shift, when air pressure was removed, a net gain in depth of only 1 foot was made, while at other times only 3 inches were gained.

Poling boards were used beneath and in the rear of the cutting edge to hold back the material which had a decided tendency to heave, but with little effect. In some instances over 4 feet of sand and gravel rushed in when the pressure was removed, requiring nearly an entire shift of work to remove it.

In order to increase the weight of the cylinder, hundreds of tons

of pig-iron were placed upon the deck and walls in the endeavor to drive the cylinder down, but even under this added weight it still remained firm.

The sand used as a guide had shifted and the surrounding ground settled or slumped, carrying sheathing and channel-iron rings with it to such an extent that the head-house was unstable, a cavity extending nearly 10 feet from the cylinder in all directions being open. Heavy timbers were placed to span the hole and support the superstructure, being held together with heavy chains.

It was decided at this time to drive a square set of sheathing outside the circular set originally placed, in an attempt to reach the channel-iron rings which were evidently jammed between the steel cylinder and the original sheathing; also to support the earth and prevent further caving. This was accomplished with considerable difficulty, it being found that the rings were in close contact with the cylinder, being much lower on one side of the cylinder than on the other; also that the heads of a few of the rivets used in making the joints of the cylinder had been entirely cut or scraped off as it had slid through the ring. Two rings were cut and the accessible portions removed, after which a boulder that had slid in and bound against the cylinder was broken and removed.

The work of excavating was recommenced beneath the cylinder after sections of the tube leading from the air-lock to the deck had been placed in position, and the cylinder was lowered after continued and discouraging efforts, as at no one trial did it go down more than 20 inches.

Grade lines were drawn across the cylinder on June 23 and preparations made for a final drop to the required grade. After the air pressure was removed the structure settled gradually, and when the desired point was reached, the air pressure was applied, but before there was sufficient pressure to counteract the weight, it had settled nearly 1 foot below the line.

A space was immediately excavated below the cutting edge and poling boards placed in such a position as to allow for the placing of a concrete foundation of much larger diameter than the cylinder. The center of the excavation was dished to a depth of 8 inches below the sides or ends of the poling boards, the material at the bottom and upon which the foundation was placed consisting of a mixture

of coarse and fine hardpan gravel, in which, on account of its firmness, it was difficult to make an impression with a pick.

A pressure of 17 pounds per square inch was maintained while depositing the concrete for the foundation, placing the waterproofing, and until the whole mass had firmly set; the cavity around the shaft was filled and preparations made to extend the walls of the shaft upward.

The power plant upon this work July 1 consisted of three boilers, including the one used in connection with the hoisting engine, all being piped together and making a total of fifty horse-power to operate the hoisting engine and compressor. At this time it was decided to make a trial of the use of cement grout to harden the ground through which the tunnel was to be driven. A small 2-inch opening was made in the steel cylinder in the upper part of the eye 12 feet in diameter, which had been left free from concrete when the walls were formed, a thin mixture of grout was prepared and an attempt made to force it into the sand and gravel surrounding the steel casing, but after several attempts the idea was abandoned, as it seemed, under existing conditions, impracticable, it being only possible to solidify a very small section of the material directly surrounding the delivery point of the grout.

As the excavation was progressing at the different levels, corresponding to those through which the tunnel was to be driven, careful examination was made, with the result that when it was found that the solidification method was impracticable, recourse was had to the original method of using steel plates to support the earth above and upon the sides of the tunnel, while the masonry walls were placed with the aid of compressed air. A supplementary agreement was drawn and the contractor granted permission therein to use steel plates in place of ring timber provided that the masonry walls, including the waterproofing and plaster, were constructed to a minimum thickness of 18 inches, a thickness equal to the proposed ring-timber and brick wall. This agreement was signed, plates ordered, and preparation made to cut out the eye. On July 3 a 50 horse-power upright boiler was added to the existing plant. The work of cutting the steel cylinder progressed very slowly on account of the disadvantages under which the men labored, the positions necessarily occupied in

holding and striking the points being decidedly awkward. After about 170 hours of continuous work by entire shifts with diamond points, a part of the upper portion of the eye was removed and it became evident that the channel-iron rings which were mentioned as having been used as a support for the original sheathing were to continue to disturb operations. Directly across the opening made in the side of the cylinder two of the rings were found twisted completely around each other, having been carried down at least 18 feet while in close contact with the cylinder, thus causing friction which retarded the settling of the cylinder. The sections of rings spanning the eye were cut out and the excavation continued.

As there was no clay encountered in this work, the necessary amount of clay was hauled from the location of an old clay pit near the corner of Bond Street and Western Avenue, a distance of about 800 yards. This clay was not of the best quality for this work but was as good as could be readily procured, the disadvantage in its use being that upon application to the gravel breast and plate-joints it dried, causing crevices to immediately appear through which the air freely issued; consequently, it was necessary to keep men continually employed dampening and renewing the clayed surface.

On July 12 the need of an addition to the air compressor plant was noted, as the small high-pressure engine delivering about 300 cubic feet of air per minute seemed to be inadequate, the temperature in the heading rising to such a degree that an effort was made to cool the air with water and ice previous to sending it into work, and thus enable the men to work freely. The opening in the top of the eye was only 18 inches in depth at this time, and on account of the loose nature of the ground the single compressor was working to its full capacity in order to maintain sufficient pressure to keep the water away from the breast.

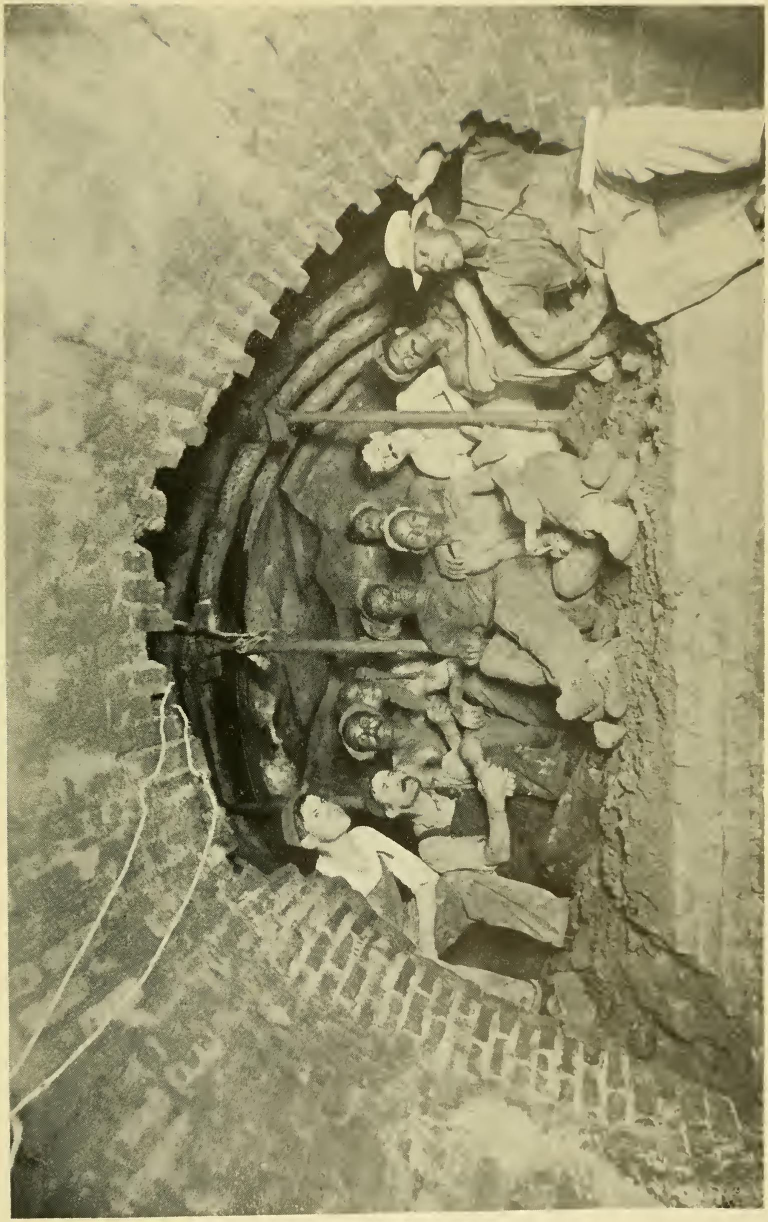
A few small boulders were encountered in this first opening, which were removed without difficulty. For four full days, or eight shifts, the men labored in excessive heat, depending upon the one compressor, and succeeded in driving the arch of the tunnel a distance of four plates, or 4 feet from the side of the vertical shaft. After two more rings were added it was decided to

suspend operations and seal the heading with clay until another compressor could be installed, as it was decidedly dangerous to excavate further and depend on the one compressor then operating at its full capacity to maintain the required pressure.

On July 22 another high-pressure compressor capable of delivering about 800 cubic feet of air per minute was installed and in operation, working in conjunction with the other, and the work was again rushed forward.

The contractors at this time realized the necessity of still further increasing the plant by the addition of another boiler, as the three small boilers on the work were taxed nearly to their entire capacity. When the arch had been driven a distance of 8 feet the needle-beam, consisting of a timber 10 feet in length, 12 inches square, was placed in position, and the work of removing the lower half of the eye of the cylinder was commenced. The plate-joints and breast were completely covered with successive coatings of clay to hold the air, and even then it required the operations of both compressors at a high speed to maintain sufficient pressure, the thermometer registering 100 degrees in the heading and 90 degrees in the lock. The continuous labor (eleven hours) in humid compressed air at such high temperature began to affect the laborers and they were obliged to come out through the lock at intervals for change of air. On July 27 the brick masons laid the first section of invert and completed the arch and work around the eye on July 29, laboring in the intense heat nearly forty-five hours to complete the section 6 feet in length.

A temporary bulkhead of plank and bags of clay was placed in the invert at the end of the completed section, and the heading again opened. While this work had been progressing, another boiler (capacity 150 horse-power) had arrived, the entire plant being connected and in working order on August 3; the heading had now been extended a distance of 12 feet through coarse gravel and boulders. At this time the larger of the two compressors became jammed and was out of commission for a few minutes, the whole load resting on the small compressor. During the strain this compressor turned 140 revolutions per minute, and although the pressure gradually dropped, the single engine held sufficient pressure until the defect was repaired and both were running.



HEADING AND BENCH.

It was evident to the writer that there was not a sufficient duplication of plant upon the work, and in consequence he requested the contractors to still further add to the existing plant a compressor delivering at least 1100 cubic feet of air per minute. Under the conditions, it was unsafe to carry on operations in the heading, not only on account of the danger to the laborers, but also on account of the danger of loosening or the caving in of the breast and the loss of time in again recommencing operations.

On August 16, 26 feet of the walls of the tunnel had been completed, and the contractors had decided to send a third compressing engine to the works, had procured a large low-pressure machine, capacity 1100 cubic feet per minute, and assured the writer that it would be in operation within a few days.

At various times during the progress of the work, the Board of Water Commissioners viewed the work, passing the air-lock with slight difficulty. A few others who were perhaps especially interested in the nature of the work or the methods used, succeeded in reaching the lower levels under pressure, but the majority of the citizens preferred to keep at some distance from the works, being satisfied to inspect the men as they emerged from the outer door of the lock in a cloud of steam.

The contractors kept in touch with the work, and knowing well the delicacy of the operation of driving the tunnel through the coarse gravel and stray boulders that might be encountered, suggested a decided change in the method of construction. Under the bed of the canal the roof of the tunnel was to be constructed within 11 feet of low-water mark, the bed of the canal being practically dry at low tide. The amount of material above the work was deemed insufficient to hold sufficient pressure to allow for the construction of a full section of the tunnel wall; therefore it was decided that when the completed walls had been erected to within a safe distance of the canal, the upper half or arch should be driven and the arch wall completed under and as far as the westerly side of the canal to a point beneath the retaining wall.

The last addition to the plant consisted of a large low-pressure compressed air engine, having a capacity of 1100 cubic feet per minute, and was installed and in operation on August 23. It was found that the difference in the temperature in the tunnel was

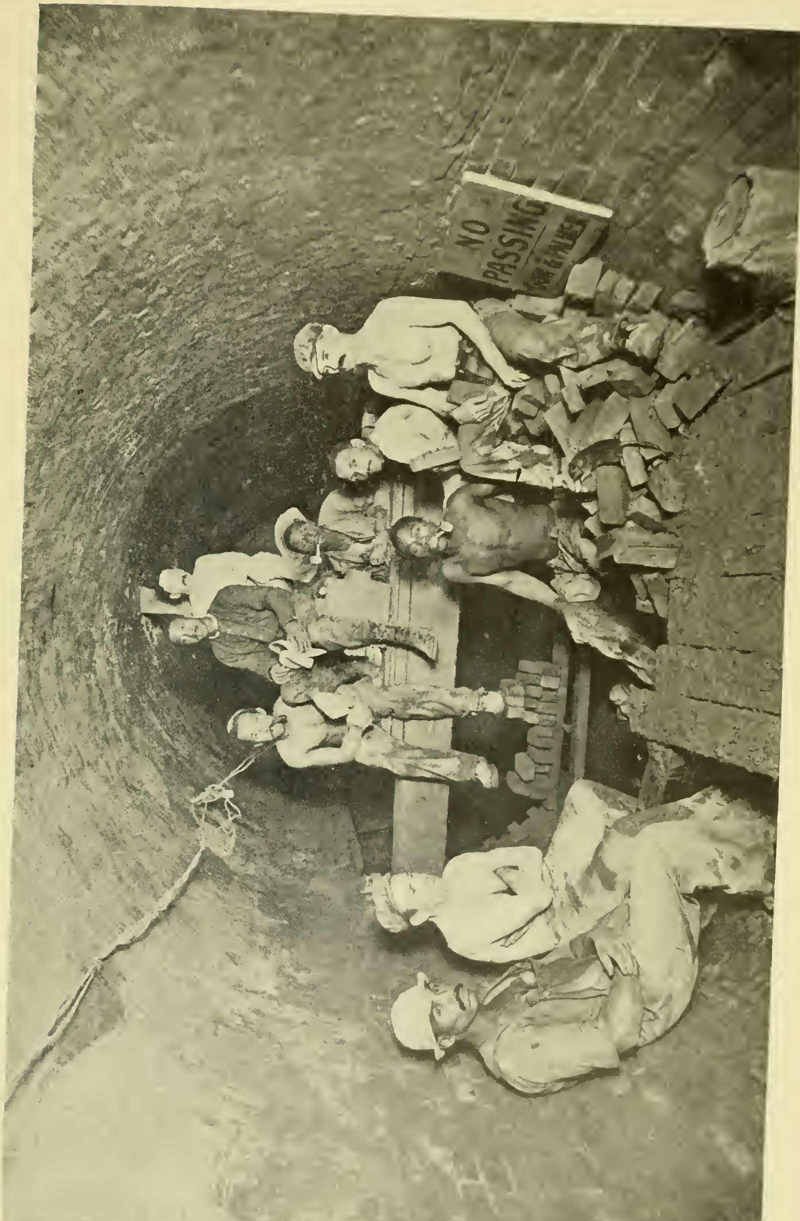
about 20 degrees, being much lower than when the air was supplied by the small compressors; it was also noted that sufficient air could be supplied by the new engine and half speed on the second machine, allowing for repairs on the third or smallest engine.

The work hereafter progressed more rapidly, and on August 28 46 feet of the tunnel wall was completed, and on September 1 a gain of 10 feet additional had been made.

At a point about 56 feet from the easterly shaft a temporary bulkhead was erected, filling the bottom of the tunnel or invert to within a few inches of the spring line, composed of a brick wall 12 inches in thickness and backed by clay puddle. This dam or bulkhead remained in place until the arch walls were completed under and beneath the western walls of the canal. During the construction of this arch about 9½ pounds of pressure was sufficient to carry on the work. When the tunnel had been driven to a point within 20 feet of the easterly canal wall a slight leakage of air was noted in the waters passing through the canal. This disturbance continued to increase as the work was extended, and when it had progressed to a point directly beneath the canal, the air rushed up through the waters in such volume from the heading that the canal for its entire width and a distance of 50 feet up and down stream resembled a boiling caldron, which was watched with much interest and speculation by large numbers of people from the bridge.

This work of driving the arch had progressed only a few feet when a boulder was uncovered in the roof extending across the heading for a distance of 5 feet and hanging into the opening about 2 feet. A few light charges were fired in small hand-holes made on the under side of the boulder, but no marked effect was made. Drilling and splitting was then commenced, and after nearly a week of continuous work the roof-plates were made secure beneath the stone, a sufficient amount of the boulder having been removed. Several small boulders were found, split, and removed from the heading, remaining in the completed tunnel until the air deck was removed, as they were too large to move through the lock.

During the progress of this part of the work the ground occupying the position of the invert remained undisturbed, the bench or



HEADING. TUNNEL NEARLY COMPLETED. INVERT UNDER CONSTRUCTION.

ground below the spring line being covered with a layer of clay 6 inches in thickness, having an overlayer of boards. It was quite a difficult task and required continuous watching to keep the pressure at an amount sufficient to keep the water from entering under and through the clay floor, and again not enough to lift the canal bottom and cause a blowout, it being necessary to watch the rise and fall of the tide and regulate the pressure according to its different levels.

During this part of the work the smallest error in air pressure could but result in severe monetary loss to the contractors and possibly the loss of the lives of the men employed in excavating the heading. The materials excavated were coarse sand and gravel, through which the air rushed freely when not retarded by the coating of clay applied from within, and was removed from its original position by small trowels. This gravel, after being dug out with the trowels and dropped on the bench, was shoveled into a single wheelbarrow and transferred to the shaft. Here it was again shoveled into a bucket to be lifted into the air lock. From the lock it was dumped in carts and hauled to the dump. Thus it will be understood that the gravel excavated was handled five different times before being finally dumped, making the expense heavy.

Several times during the perilous part of the work on the arch, the earth was driven upward by the air pressure or fell away, leaving a large aperture through which the air roared to the surface. During these periods the whole compressor plant was operated to its entire capacity; these voids were immediately filled with clay, bags, or any cloth or material which would stop the outrush of air, the miners knowing that were these voids not filled at once the pressure would relax and the waters from the canal and the harbor rush in. On September 21 the arch was completed to a point about 14 feet from the western shaft and beneath the westerly side wall of the canal, and a solid brick bulkhead erected. This bulkhead was built within the completed arch and about 1 foot back from the toothing, thus leaving sufficient brick work for connection with that part of the tunnel which was to be built from the westerly shaft.

The first temporary brick bulkhead was now removed and the

invert constructed, the connection between the arch and invert being made tight by splitting brick in form of a wedge and driving tight. This being neatly executed, the circular section was made complete to the terminus of the work to be accomplished from the east side. The bulkhead having been completed and braced by heavy raker timbers stepped into the brick invert, the air pressure was removed and the air tube and lock transferred and fastened in position in the west cylinder, the air and water supply pipes were suspended over the canal, the head-house placed in position, and the work of settling the western shaft commenced on October 6.

The west cylinder, having timber guides, settled rapidly, the cutting edge being kept in contact with the bottom, slipping down when the air pressure was slightly reduçed; thus the trouble of the heaving of gravel, as was experienced in sinking the east shaft, was avoided, and on October 9, 12 feet of progress downward had been accomplished. On October 13 the cylinder reached the required level and the concrete walls were extended upward toward the surface. The excavation was made and foundation placed similar to that in the east shaft, and the work of cutting out the eye of the tunnel in the steel cylinder commenced. The levels and lines were transferred through the deck and preparations made to excavate for the arch. This work was commenced on October 19 and six days thereafter the toothing of the completed section and bulkhead was met, and on October 30 the continuous walls of the tunnel were complete from the east to the west shaft. The work of calking, cement washing, and finishing was begun immediately after the bulkhead was removed; the fires were drawn in the larger boiler and it was removed. On November 4 the night shift was discharged, the work thereafter being carried on by one gang during the day. Three days thereafter the air pressure was withdrawn, and the writer was gratified to note that there were very few damp spots throughout the entire length of the tunnel. Several small leaks appeared in the west shaft which were readily stopped when the air pressure was again in use.

The drains from the west shaft to the east shaft were laid, above which the ducts (six lines of six multiple vitrified duct) were laid

Plate IV.

Site of Tunnel, and Contractor's Plant.

This view was taken when making the connection between the

in the invert or bottom of the tunnel, air pressure of 15 to 20 pounds per square inch being maintained until all were in place and covered with concrete. These six lines of duct were divided into two sections, being imbedded in the concrete, the joints waterproofed, and separated by a wall of concrete 1 foot in thickness, one side to be occupied by high tension, the other by low-tension cables; the concrete covering was overlaid with fine plaster, which serves as a floor.

The pneumatic pressure was finally removed on November 16 and members of the Water Board inspected the structure, together with the writer, and expressed satisfaction with the work, the total leakage being unusually slight.

The water mains, two lines of 20-inch cast-iron pipe, were next placed above the floor, supported upon brick piers on either side of the tunnel, the 12-inch gas main being supported in like manner in the center. These lines of pipe were extended up through that portion of the shafts designed for their occupancy, and the partition walls erected.

The ducts were wired, a line of wire extending from one shaft to the other through each duct to serve as a lead wire when placing the cables later.

The reinforced concrete roofs or covers were laid and the manhole caps and covers placed in position, the grounds around the shafts were graded, and the tools and machinery removed. The Board visited the tunnel on December 22, together with the writer, and after a thorough inspection, decided that the difficult task of building a practically waterproof tunnel and appurtenances under numerous disadvantages had been acceptably completed, and upon the following day the contractor was notified of the acceptance of the work.

The leakage of the tunnel and shafts is at this time much less than in any tunnel now completed in this country of which the writer has knowledge, being less than one-half gallon per minute, with evidence that this will be reduced in the future. When the material through which this work was built is considered, together with the several obstacles encountered, the contractor is to be congratulated upon the success of the undertaking and the fact that no person was injured during the work. The absence of

leakage in the brick walls of the tunnel is due in part to the excellent work of the two masons, George H. Eaton and Michael Ferriter, who laid up the walls under pressure and in extreme high temperature, and whose work, accomplished under the several difficulties, is certainly commendable.

To Mr. Charles B. Lewis, who acted as foreman in charge of the work for the contractors, is due the credit for close and unceasing care in the handling of all parts of the work, and of completing a wholly satisfactory piece of work.

The entire engineering work connected with this tunnel, viz., location, design, drafting of plans, including all general and detail plans, together with the drafting of the contracts, was executed by the writer in person, who also acted as resident engineer and inspector during construction, the only assistance required being furnished by the timekeeper and foreman employed by the contractor as per the terms of the contract.

A small vertical centrifugal pump was submerged at the bottom of the collection sump, being operated by an electric motor located directly beneath the roof of the shaft, the connection between pump and motor being made by a shaft bracketed to the side walls.

A float and automatic switch were included in the appurtenances to the pumping plant, and the water collected is of such small quantity that the automatic action of the pump occurs at intervals of fourteen days.

When the structure has been closed for a considerable time, moisture of condensation collects in the arch and upon the mains, which finally reaches the sump, but when the manhole covers are removed and a strong draught is allowed to circulate for an hour, the walls of the tunnel and shafts are sufficiently dry to allow the lighting of matches on the cement-washed surfaces.

Electric cables have been installed in the ducts, the gas and water mains have been in constant use practically since the acceptance of the work, and no trouble has as yet been noted; hence the practicability of a small sub-aqueous tunnel for the location of water and gas mains together with electric cables has been demonstrated to our entire satisfaction.

COMPLETED TUNNEL.

A CITY'S RIGHT TO METER PRIVATE FIRE SERVICES.

SHAW STOCKING COMPANY *v.* CITY OF LOWELL.

Supreme Judicial Court, Massachusetts, Middlesex, May 22, 1908. (*85 Northeastern Reporter, 90.*)

SHELDON, J. We see no reason to doubt the authority of the water board of the defendant city to make the regulations here in question. These regulations require that all water supplies from the city's mains to the premises of any water-taker for the purposes of a private fire system shall pass through a meter, and that this meter shall be furnished and set by the city at the expense of the owner of the premises served.

Authority to supply water to its citizens was first given to the city of Lowell by Stat. 1855, Chap. 435. The third section of this act empowered the city, among other things, to construct and maintain proper aqueducts and pipes, to establish public hydrants, to prescribe the purposes for which they should be used, and to change or discontinue the same; to distribute the water throughout the city and to regulate the use of said water, and establish and collect the prices to be paid therefor, and also to do any other acts or things necessary or convenient and proper for carrying out the provisions of the act. Additional statutes have since been passed, but the power and authority of the city have not been diminished by any of them. See Stat. 1866, Chap. 200; 1869, Chap. 351; 1870, Chap. 321; 1893, Chap. 412; 1895, Chap. 247.

By Chapter 45 of the Revised Ordinances of Lowell, the powers thus given the city have been vested in its water board, in pursuance of the permission given by Stat. 1855, Chap. 435, Sect. 5.

The defendant has not required and does not purpose to require in future any payment for water used in extinguishing fires. The principal object of the defendant's water board in requiring fire-service pipes to be metered is to prevent the surreptitious or careless withdrawal of water through such pipes for other purposes than the extinguishment of fires; another object is to procure the

measurement by meter of all water consumed for any purpose in order to check wastage and to require each taker to pay for the exact quantity of water furnished to him. The requirement is well adapted to aid in accomplishing these objects; and this is none the less so, although its operation sometimes may be circumvented by some fraudulent device. The regulation must be regarded as reasonable unless some of the plaintiff's specific objections to it can be sustained.

The plaintiff contends that it ought not to be required to pay for the meter to be applied to its private fire service pipes. Its counsel relies upon the decisions in Red Star Steamship Company *v.* Jersey City, 45 N. J. L. 246; Albert *v.* Davis, 49 Neb. 579; Smith *v.* Birmingham Water Works Company, 104 Ala. 315; Spring Valley Water Works *v.* San Francisco, 82 Cal. 286, 316; and Sheffield Water Works *v.* Carter, 8 Q. B. D. 632. But these cases differ from the case at bar. They generally turned upon the language of the statutes under which they arose, or the provisions of the contracts which were before the courts. In this case it has been found by the court below, with evident correctness, that the defendant is under no legal obligation, by contract or otherwise, to furnish the plaintiff with water for its private fire-service system. Under the present circumstances, we prefer, so far as it is a matter of precedent, to follow the carefully reasoned opinions in Sheffield Water Works *v.* Bingham, 23 Ch. D. 443, in which the earlier case of Sheffield Water Works *v.* Carter, *ubi supra*, is fully discussed; and State *v.* Gosnell, 116 Wis. 606, decided in 1903, in which the earlier decisions are reviewed. Both upon principle and authority we are of opinion that under circumstances like those before us it is not unreasonable to require the installation of a meter at the plaintiff's own expense in its private fire-service pipes.

Nor can it be said that this regulation imposes undue burden upon the plaintiff. The defendant has afforded reasonable means of extinguishing fires by public hydrants; if the plaintiff desires in addition a private system for the protection of its own buildings, it is not unfair for the defendant to impose, as a condition of supplying without other charge water to make this system available, the requirement that the plaintiff shall take this water only through a meter to be put in at the plaintiff's expense. The defendant's

duty to supply water at reasonable rates to all takers without discrimination, so far as this duty exists (see Merrimack River Savings Bank *v.* Lowell, 152 Mass. 556, and Lombard *v.* Stearns, 4 Cush. 60), does not carry with it any obligation to supply water free of charge for the plaintiff's private system of safeguarding its property.

Nor has there been unjust discrimination against the plaintiff in the enforcement of this regulation. The rule is a general one, applicable to all persons who maintain a like private system. That it has been put in force only gradually, beginning with the worst or the most important cases, affords no reason for enjoining its enforcement in any particular case. Parker *v.* Boston, 1 Allen, 361. Ladd *v.* Boston, 170 Mass. 332. Wagner *v.* Rock Island, 146 Ill. 139.

Accordingly, the decree of the Superior Court dismissing the bill must be affirmed; and it is

So ordered.

METERS AND WATER CONSUMPTION OF THE HARTFORD WATER WORKS.

BY ERMON M. PECK, ENGINEER IN CHARGE OF MECHANICAL DEPARTMENT, HARTFORD, CONN.

[*Read September 24, 1908.*]

When the big new Tumble Down Brook Reservoir was completed in 1895 it was predicted confidently by many wiseacres that Hartford would not need another reservoir for many years to come. The population of the city at that time was about 66 500.

In December, 1899, only a little more than four years later, with a population of about 80 000, or only about 13 500 greater, the city suddenly found itself confronted by one of the worst water famines in its history. To produce this condition of affairs two factors were dominant, viz., unfavorable occurrence of rainfall and consumption greatly in excess of its needs. In this exigency the hustle gong was sounded for the construction department and in record-breaking time, pumps, boilers, intake, and a new force main were installed only to " die a-bornin' " ; for, with all the irony of fate, on the very day upon which the new plant was to be tested, Jupiter Pluvius deluged the earth, and Hartford's latest water famine passed into history. In the meantime, however, for several weeks the decrepit old pumping plant which had been used to supply the city from the Connecticut River nearly half a century before had been started into action and limped along until one morning, crystallized from many years of overstraining, the piston rod of its engine broke and the fortune of the Hartford Water Department looked darker than ever. The Hartford Street Railway Company was our good angel in this dilemma, and its general manager very kindly furnished and installed a motor to operate the pumps, so that in a few hours we were able to force filthy Connecticut River water into our mains with as much gusto as formerly, and continued to do so until the occurrence of the storm noted above.

When the drought was broken and our nervous system was

relieved of the temporary strain it was evident that something must be done.

The department had two inspectors who regularly covered the city twice per year on the assessment plan, and while these men knew that many leaks existed and that gross abuse prevailed along the line of permitting faucets to run to prevent freezing of pipes in very cold weather, their duties were too arduous to allow them to make detailed inspection for the purpose of detecting these sources of waste. Accordingly, 10 additional inspectors, one for each ward, were employed, who shortly gave good accounts of themselves by the number of premises where water waste occurred which they reported. These reports, coupled with the recent shortage, spurred the board of water commissioners on to adopt the policy of general metering of service pipes. It was planned to complete metering the city in about three years, and this was very nearly accomplished.

The following table is an exhibit of the number of meters in use and the daily per capita consumption by years. The 84.6 gallons per capita opposite the year 1900 may be taken as the best information we have of the per capita consumption previous to general metering, and was computed from scattering Venturi meter readings. In 1902 the automatic register was attached to the Venturi and since that time the records are reliable.

Year.	No. of Services in Use.	No. of Meters in Use.	Per Capita Consumption, Gals. per Day.
1900	8 951	550	84.6
1901	9 256	2 783	76.3
1902	9 514	6 993	78.8
1903	9 683	9 156	75.0
1904	9 809	9 604	66.7
1905	10 006	9 860	62.6
1906	10 328	10 137	61.6
1907	10 623	10 433	59.1

These figures are based upon the total population supplied, which at present is estimated to be divided as follows:

Estimate of population in Geer's 1907 Hartford Directory	106 000
Population supplied in the towns of West Hartford, Wethersfield, and Bloomfield	3 000
Floating population, equivalent to regular consumers	4 000
	113 000

The estimate of the floating population was arrived at by stationing observers at the outskirts of the city on the various trolley lines to count the passengers bound cityward. Similarly observers were placed at the Union Railroad Station. Each "floater" was estimated as one-third regular consumer.

At the present time the department has 10 922 services and 10 814 meters, 99 per cent. of the taps being metered. This is a high percentage compared with that of most other cities.

It should be said in this connection that the above reduction in the consumption of water has not been accomplished by meters alone, but partially by a rigid waste and leak inspection which has gone hand in hand with it. Inside the premises the inspection has been prosecuted by the meter readers. In the streets the water mains, services, hydrants, etc., have been inspected regularly by parties of men who did nothing else. The early experiences of this leak survey party were marked by the discovery of many leaks, some large and of long standing. The leak survey was established in 1902, but did not operate extensively until 1904. The large drop in consumption for that year I consider largely due to its work.

The rise in consumption in 1902 I consider due to the fact that the "big bill bogey," always easily conjured by the excited mind of the water taker, had failed to materialize, and the reaction towards increased consumption usually noted in such cases had set in. This, of course, was cut down in the succeeding years by fighting waste and leaks.

In this connection I may say that a very interesting computation was made during the past year, designed to show the proportion of the water passing the Venturi meter at the distributing reservoir which could be accounted for. After making proper allowances for unmetered water and under-registration of meters, it was found that only 16 per cent. of the water as registered by the Venturi remained unaccounted for. Since that time several of our fire service pipes have been metered, with the result that this percentage could be somewhat reduced.

Recently the board of water commissioners has become impressed with the importance of systematic tests in order to keep the meters within permissible limits of registration. We require

all meters to test not lower than 98 per cent. and not more than 100 per cent. on full flow.

All new $\frac{5}{8}$-inch, $\frac{3}{4}$-inch, and 1-inch meters are required to register 75 per cent. on a $\frac{1}{32}$-inch stream under the pressure at our testing bench, which would be equivalent to a flow of .0230 cubic feet per minute, and after they have been in service they are required to register on this flow. It is the intention to test all meters at least once in four years, and perhaps oftener.

Meters larger than 1 inch are required to test more in accordance with the service for which they are used than by a fixed rule, although, as a general proposition, $1\frac{1}{2}$-inch and 2-inch meters, after being in service, are required to register 50 per cent. on a $\frac{1}{16}$-inch stream, — a flow of about .113 cubic feet per minute, — the other requirements being the same as for smaller meters. The larger part of the meters above 2 inches in size are being fitted out to be tested in place. This is done by putting a valve in front of the meter with a hose connection between the two. To test the meter, the valve on the service is closed and the hose connected up with an accurate meter in series with the one to be tested as in the following sketch. (Fig. 1.)

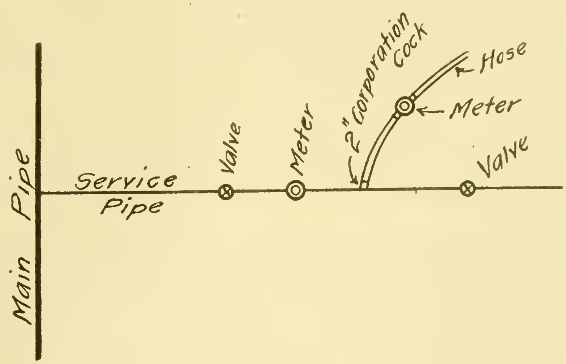


Fig. 1.

In laying new services the following plan has been adopted (see Fig. 2): *A* is a valve on a by-pass around meter. This valve is closed and locked at all times excepting when meter is being tested.

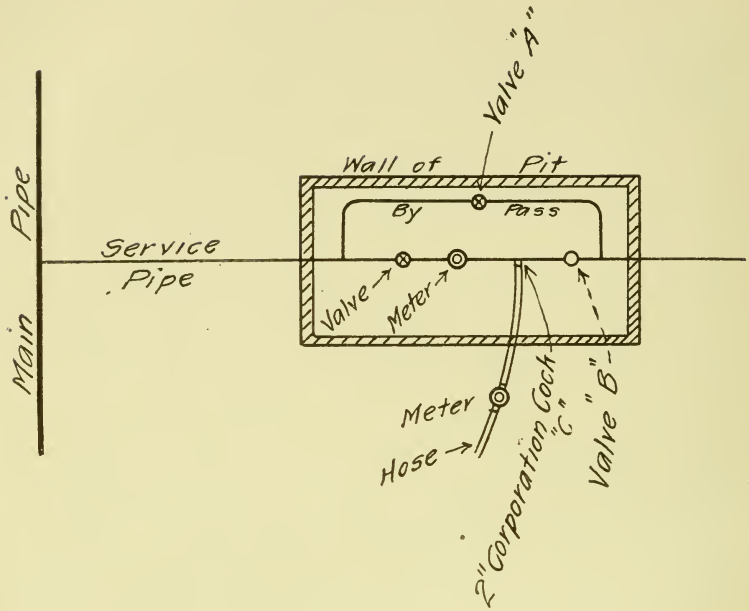


FIG. 2.

B is a valve in front of meter, and *C* is a corporation cock for connecting up hose with accurate meter. To test meter, hose is connected up as in the sketch above. Valve *A* is then opened and valve *B* is closed.

The whole arrangement of valves and by-pass is placed in a concrete pit. By this method, large meters can be tested without shutting off the supply from the consumer, which is often a great consideration.

Although this method of testing large meters has been in use for some time in other cities, it has not been employed in Hartford any more than experimentally to ascertain its practicability until recently. A party of men was at work for some time during the past winter fitting up the larger services for these tests.

It is our intention to test all the meters so arranged at least once each year, and in some cases twice.

The meter card which has been lately designed for the Hartford Water Board, is a large one, being approximately 9 inches by 14 inches. It is ruled and printed on both sides, one side being

devoted to information regarding installation and the other to maintenance. An 18-inch Elliott-Fisher billing machine is used for writing up the cards.

The writer may add that the card system has been adopted recently for the meter readers' books, and these, too, are written upon this machine.

DISCUSSION.

Mr. Allen Hazen.* I should like to ask Mr. Peck if he has ever made a calculation of the amount of water used for manufacturing purposes that is drawn from other sources than the supply pipes. That is, of itself, a very important matter, and I know that in Hartford a great deal of water is drawn from the streams for manufacturing purposes, in addition to what comes from the public supply; and wherever the per capita consumption is stated, I think that it is important to have go with it a record or statement of what the conditions of the use of manufacturing water are.

Mr. Peck. That is a question which came up about a week before the meeting, but we had no means of answering it. We are liable to have to make some estimate of it before a great while, but at present I cannot give it. It is a large amount of water; there is no question about that.

Mr. Hazen. The factories draw the greater part of their water from other sources than your supply; that is true, isn't it?

Mr. Peck. Some of them do, not all of them; I would say a large part of them.

Mr. M. N. Baker.† Has there been any material change since you began metering in the amount that manufacturers take from other sources?

Mr. Peck. No, I do not think so. I do not think it has been affected at all by putting on meters.

Mr. H. N. Parker.‡ I should like to ask why you took the consumption of the floating population as one third. Is that

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* Of Hazen & Whipple, Consulting Engineers, New York City.

† Associate Editor *Engineering News*, New York City.

‡ Assistant Hydrographer, United States Geological Survey, Washington, D. C.

based on any estimate of time that a visitor to the town was likely to stay there, or what reason was there for using that figure?

Mr. Peck. That is just what I based it upon. I tried to hit upon some scheme for fixing a value for the "floaters," and I arrived at it in that way, by considerng, perhaps, that the proportion of the water they would use would correspond with the time spent in the city.

The President. Perhaps it might be interesting if Mr. Peck would tell us whether he is using many detector meters on the fire services, or how he meters those.

Mr. Peck. We have a few detector meters in use.

METER RATES.

BY WALTER H. RICHARDS, ENGINEER AND SUPERINTENDENT, WATER AND SEWER DEPARTMENT, NEW LONDON, CONN.

[*Read September 24, 1908.*]

The subject of meter rates has been much discussed, both in this Association and others, but a few points remain to be brought out in an otherwise threadbare subject, and it is with this in view that this paper is introduced.

Up to this time meters have been installed primarily to prevent waste, and there is no doubt that in this particular the meter is successful. But as was so clearly shown in Mr. Johnson's able paper,* the per capita use is constantly on the increase, due to the legitimate consumption through an increased number of fixtures and from other causes. The per capita consumption varies considerably with the character and habits of the population; for instance, Woonsocket, with 91 per cent. of its services metered, has a per capita consumption of 29 gallons per day, while Newton, with 86 per cent. of its services metered, has a per capita consumption of 54 gallons. .

But is it not time that we plead for measured water on the ground of equity? Why should any intelligent engineer of water works undertake to defend the so-called schedule rates which, if he is well informed, he knows to be full of inconsistencies?

If it is argued that it costs no more to procure and deliver two gallons than one, the argument fails when we apply it to larger quantities, as it often costs as much to increase the supply to a city by 100 per cent. as the amount expended for the original work.

If the installation of meters is deferred on the grounds of economy, it is clearly a subterfuge, and an injustice is resorted to, to save the cost of the necessary machinery to "deliver the goods," for the meters are undoubtedly a part of the water-works plant. To say that all stores, markets, or barber shops use like quantities,

* JOURNAL N. E. WATER WORKS ASSOCIATION, Vol. 21, p. 109.

or even that any two use like quantities, is absurd. To charge for the supply of one fixture the same as another, regardless of the number of times it is used or the length of time it is used, is clearly neither scientific or equitable. The use of meters has demonstrated that one party may use double the quantity of water that another does under precisely the same conditions, and even were this not true, the constantly increased number of uses to which water is put renders the formulation of a schedule rate for each kind and each size of fixture used by a different number of persons for different purposes entirely impracticable. Water should be sold, therefore, like other commodities, according to the weight or volume.

The charge for water, like any other commodity, should be based on its cost, and as the cost is different in different places, it follows that the rate should be different, and if the water department were conducted on an independent and on a business basis, that rate should not be below cost.

The cost of water in various cities, as shown in the following table, is obtained by dividing the total cost of maintenance and repairs, including interest on bonds,* by the total amount of water flowing into the city. This table shows great variation, the price varying from 1.8 to 0.27 cents per thousand gallons. As in some cases, however, a considerable portion of the cost of the works has been paid from the income, it is a question whether this method can be fairly used to ascertain the cost of the water; it would seem right to calculate interest on the net cost of the works; furthermore, it has been found that about 40 per cent. of the water going into a city is lost by leakage or from undiscovered wastage before reaching the consumer; hence only 60 per cent. of the entire flow should be considered.

Actual Cost of Water per Thousand Gallons Supplied.

Atlantic City, N. J.	$0.0723
Battle Creek, Mich.	.072
Bay City, Mich.	.0315
Billerica, Mass.	.1768
Cambridge, Mass.	.0659

* Journal N. E. Water Works Association, Vol. 19.

Chelsea, Mass.	$0.0442
Cleveland, Ohio	.0232
Haverhill, Mass.	.04
Lawrence, Mass.	.089
Lowell, Mass.	.1667
Lynn, Mass.	.10
Marlboro, Mass.	.1345
New Bedford, Mass.	.047
New London, Conn.	.0546
Oberlin, Ohio	.1153
Reading, Mass.	.27
Reading, Penn.	.018
Taunton, Mass.	.0983
Waltham, Mass.	.0637
Westerly, R. I.	.0878
Winchendon, Mass.	.2302
Woonsocket, R. I.	.1342

The problem, therefore, is to find the cost of water which can be delivered to customers without additional main works, from which the rate should be fixed so as to furnish, with other rates and charges, a sufficient income to provide for the payment of all interest charges and the maintenance of the works, together with such unforeseen expenditures as may be required for small extensions or additions to the works, and for expenditures due to accidents which cannot be foreseen.

A large percentage of the cost of the works is due to the increased size of the mains, fire hydrants, etc., which are necessary for fire protection, and which are for the benefit of the general taxpayer. Water for schools and public institutions is in the same category, and all this should be paid for from the tax rate. Other than the above, the taxpayer, as such, should have but a small part of the expense of maintenance of the water system.

So far as extensions of mains is concerned, after the main portion of the city has been piped, it may be provided for by the guarantee in water rates, on the part of abutting property, of a reasonable percentage on the cost of a small main of size sufficient to supply that street (say 6-inch) until such time as the regular rates amount to this guarantee.

The cost of the meter itself and the cost of setting the same must be provided for and should be a charge on each meter

sufficiently large to pay cost of repairs due to wear and breakage from frost and for renewals after the meter is worn out. Very few data are available on this subject. A charge of 10 per cent. on the cost is the rule at present, which is probably too small. The practice in some cities of charging the cost of meter and repairs to the consumer does not appear to be desirable, as the meter is a part of the water-works system and should be always under the control of the department, and to charge the cost to the consumer is simply another way of increasing the expense of the water to the consumer.

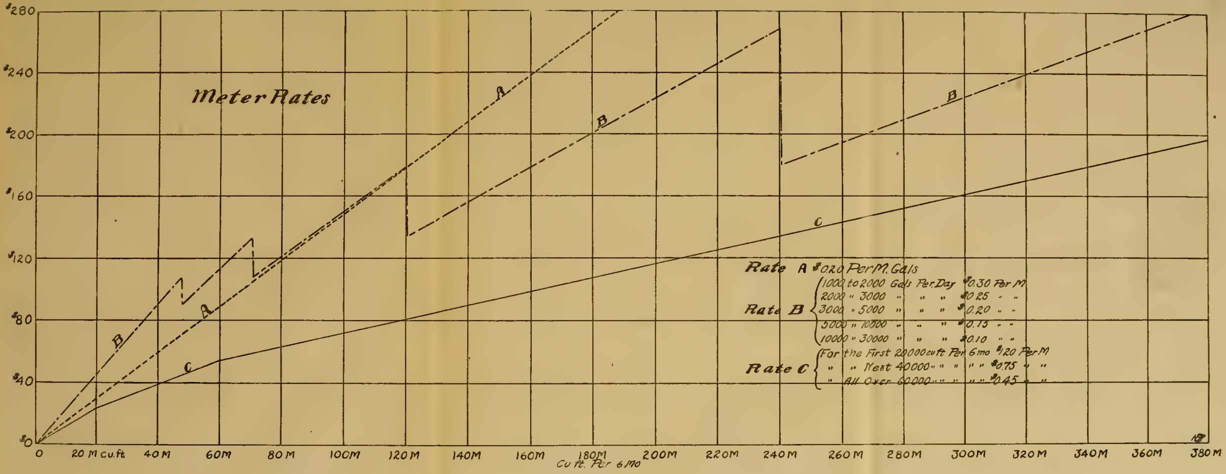
A uniform charge for all water without regard to the quantity or purpose for which it is used has been suggested, but it should be considered that a considerable portion of the expense of securing the purity of the water is to fit it for domestic use; and further, it costs but little more for service pipe and meter for a large quantity than a small quantity. For instance, a 2-inch service can easily supply as much water as twenty ordinary $\frac{5}{8}$-inch services, whereas the cost of the service is but about ten dollars more than the $\frac{5}{8}$-inch service.

To cover the cost of connecting with the mains, and other costs which are uniform regardless of the quantity of water used, a minimum rate is desirable. The practice seems to vary between \$5 and \$10 per annum. The low rate seems to be desirable as encouraging the use of meters.

The formula suggested, then, is: Divide the cost of maintenance, repairs, renewals, and interest on cost of works less that cost necessitated by the fire supply, by the quantity of water the works will supply less the leakage from mains (say 50 per cent.).

To this should be added a constant for unforeseen expenses due to accidents and for such extensions of mains as do not increase the capacity of the works.

From the above it is evident that no comparison should be made between the rates in different cities, and, as a matter of fact, there is a wide difference in meter rates. Few, however, seem to have rates fixed on a scientific basis, and many contain glaring inconsistencies. This is illustrated by the rate which charges one rate for a certain amount used in a given time and a smaller rate if a larger amount is used in the same time, by which a customer,


Meter Rates
$280
$240
$200
$160
$120
$80
$40
$0
0
20 M cu.ft.
40M
60M
80M
100M
120M
140M
160M
180M
200M
220M
240M
260M
280M
300M
320M
340M
360M
380M
Cu ft. Per 6 Mo
A
B
C
Rate A $0.20 Per M. Gals
Rate B
1000 to 2000 Gals Per Day $0.30 Per M
2000 " 3000 " " " $0.25 " "
3000 " 5000 " " " $0.20 " "
5000 " 10000 " " " $0.15 " "
10000 " 30000 " " " $0.10 " "
Rate C
For the First 20000 cu ft Per 6 mo $1.20 Per M
" " Next 40000 " " " " " $0.75 " "
" All Over 60000 " " " " " $0.45 " "

having used a certain amount, finds he will save money to let his water run. This is sometimes supplemented by an addition to the rule by which, between certain quantities, the same amount is paid.

These forms of rates are illustrated by the diagram, Plate I, "A" being the straight rate, "B" being the rate whereby a consumer gets more water for less money, and "C" being the gradually decreasing rate which gives a parabolic curve. All the curves are illustrations of rates now in use.

No water department manager need think that having decided on the rate his troubles are over, for a host of difficulties arise with every meter set.

How many meters shall be set in a building? If the department sets but one meter on a service pipe, how is the landlord to divide the charge among his tenants? If he is compelled to have a meter for each tenant, who furnishes, sets, and reads these meters? And if the rate is a decreasing rate billed to the landlord, how shall it be divided among the tenants? If the water department reads the meters, shall the department divide and bill to each tenant?

With a decreasing rate, shall the bill be calculated for each service pipe metered or all the service pipe in the building combined, or all adjoining buildings combined owned by the same owner, or all the buildings or supplies in the city owned by the same owner?

It seems best to the writer for the department to furnish, set, and read one meter for each service pipe and let the landlord divide it among tenants as he sees fit.

Where meters are required for certain uses only, shall the meter be set so as to meter all or a part of the building supplied?

While it seems absurd to have the fixtures in one room metered and those in the next room unmetered, these are conditions existing in the writer's own department.

Whether a meter should be set inside a building, in the sidewalk, or on the lawn is a question. To set meters in the sidewalk or lawn increases the expense of setting largely, but avoids danger of freezing and measures all water entering the premises; on the other hand, if set inside the building it is more easily read, especially in cold weather, and can be kept track of by the consumer.

When it is suddenly decided to meter a certain class of consumers, leaving the remaining consumers to pay schedule rates, much friction arises and the installation is made with difficulty, and, in the writer's opinion, it is much fairer and the rule is enforced with less objection on the part of consumers if all supplies are metered without exception.

In presenting this paper no attempt has been made to indicate an exact rule for calculating a meter rate or the charges for meters, but the rule is presented as a guide, each department to be guided by local circumstances. The writer's preference, however, is for a graduated rate as indicated by "C" on the diagram, and the calculation and billing for all the water which enters each separate building to the owner of that building.

DISCUSSION.

THE PRESIDENT. Gentlemen, this paper is now before you for discussion.

PROF. EDWARD W. BEMIS.* Mr. Chairman, we have been experimenting a good deal with meters, as you know, in Cleveland, and we have now perhaps more meters than in any other city in this country. We have about 68 000 meters in use. I should think from our experience that almost all the points which have been made in this paper were sound, with possibly one exception, so far as I noted. That was with regard to the graded system of rates. I think that it is necessary to have your rates so adjusted as to get the revenue necessary for the department, and it may be necessary to have a much higher rate for small consumers than for large ones. It certainly is true that it costs much more for a small consumer, in proportion to the water he uses, than it does for a large consumer; and, so far as the paper suggested a minimum rate, it seems to me that our experience in Cleveland would endorse that thoroughly.

But I was thinking more particularly of the concluding sentences of the paper, in which it was proposed to have a rate which would vary with the amount used. That is practicable, it strikes me, although we do not have it in Cleveland. We have

* Superintendent of Water Works, Cleveland Ohio.

there a uniform rate for all consumers, large and small, although we do have a minimum rate which varies with the size of the meter. It is practical to have two rates, — a rate for the first thousand feet a month perhaps, or the first two thousand feet per month, if you prefer, and a lower rate for all in excess of that. But there is an objection, and a very serious one in my mind, to having several gradations of rates for large consumers. If you simply desire to have a rate for the first one thousand or two thousand feet that shall be much higher than the rate for all in excess of that, you are not doing injustice to anybody, and you are to some extent following out the theory that, since it costs more for the small consumer, he should pay more, for there is a marked difference between the character of the consumers you would hit by your rate for the first one or two thousand feet a month and those who use more. The class that you would hit by your higher rate would be the residences, and such gradation as I speak of would give a lower rate to business properties as contrasted with residences; and, in view of the great difference in the cost of supplying to the two, that does not look to me unreasonable.

The moment you have a series of gradations between business properties, you give the large fish a greater opportunity to swallow the small ones. You then give a wholesale rate to one business man and a retail rate to his small rival in the same line of business.

That is common in private business, and we do not criticise it, — we expect it, — and I do not know, therefore, that I would expect a private water company to do very differently in that respect from a private business in ordinary lines, unless prevented by law. I am speaking more particularly now of a municipally-owned plant, and it seems to me that we more and more expect a city to give the same show to every man. Where there is a difference in cost, as there is between the small and large user, we may admit it, so far as making a higher rate to residences than to large users; but a business man competes with his neighbor; he does not compete with the residents, he does not compete with the householders, but a large hotel is competing with a smaller hotel, a large store is competing with a smaller one, a large factory with the smaller factory, and it violates my theory of the function of government to give a special rate in such case, any more than the

government gives a special rate to those who buy a large amount of stamps, whether it be for postal purposes or for internal revenue purposes. The government does not do that in any country; nor in taxes do we make a special discount to a large taxpayer.

Yet I can see how there may be cases, in a small town, where there is some one consumer, like a railroad, perhaps, that uses a very large quantity of water, with no rival in that line of business in the town at all, and where if it had to pay as high a rate as does the ordinary business it would find it to its profit to pump an inferior grade of water, perhaps, from some nearby stream. And I can conceive the propriety in such a case as that of a reduced rate, if the water works feels that it is still a profitable contract and better than not to have the business at all. I think that is to be avoided if it is possible, and I am only speaking of a possible exception where a town wishes the revenue, and cannot get it at all from such a large consumer unless it makes a further third rate, we will say, or a third step in the gradation for such a class of users. But I wouldn't do it then, I had rather lose the consumer, if it means discriminating against some rival in the same line of business. It strikes me that we cannot do that in a municipal plant, and I do not think we would have to do it. I think we can accomplish what we are after by having a minimum, and then, perhaps, having two gradations in our rates.

Mr. W. C. Hawley.* Mr. President, I do not understand why a municipality should do its business any differently than a private corporation. As I understand the matter, furnishing water is not a municipal or governmental function, such as police protection, fire protection, or building streets. At any rate, in some states it has been decided by the courts that when a municipality enters upon the business of selling water, it does so on exactly the same basis as any private corporation. That being the case, it seems to me that the principle of wholesale and retail ought to enter into its business.

It is a difficult proposition to establish a schedule of rates along the lines which have been pointed out or suggested, and incorporate in it that principle of wholesale and retail business without

* General Superintendent, Pennsylvania Water Company, Wilkinsburg, Penn.

inflicting a hardship upon some portion of the consumers. It seems to me that it could better be done by taking into consideration those costs of furnishing water, such as interest, depreciation, sinking fund, maintenance, — taxes in the case of a private corporation, — and general expenses, such as salaries, office expenses, meter reading, etc., which have nothing to do with the quantity of water furnished, and dividing those costs among the consumers. Probably the best unit in that case would be the unit of family. Of course you have got to include the business houses, etc., and there will be some difficulties in arriving at an exactly equitable division, but some basis can be found by which those costs which bear no relation to the cost of furnishing water, that is, the pumping of so many gallons, can be divided accurately among the consumers, and thus a minimum rate fixed. Then take the cost of furnishing the water, pumping, filtering, etc., and fix that at a reasonable price, and let that water be sold in addition to the minimum rate which has been established by dividing the other costs among the consumers. In that way the benefits of the plant will be conferred upon all at equal rates, and a large user of water will get his supply at a somewhat lower price than the small user. In other words, the principle of wholesale and retail will obtain.

I am glad to see that the writer of the paper speaks of dividing the cost of the plant, and, in arriving at the cost of water furnished, includes only that portion of the plant which is not necessary for fire protection. It seems to me that there is a line which we water-works men must draw and emphasize, until the public at large is educated to the difference between the expense of furnishing water, — so many thousand gallons, — and the expense of furnishing fire protection. A company with which I am connected has recently had a case which has gone through the Supreme Court of Pennsylvania on that very point. The question came up as to what was a reasonable rate for fire protection. We called in experts and we designed a plant covering exactly the same ground as the plant in question, but to supply domestic and manufacturing use only. Fortunately there was very little manufacturing involved in that case. We took the fair value of the plant as it stood, and deducted from it the cost of a plant

for domestic and manufacturing service only, and the difference we maintained was the cost of furnishing fire protection, and that on that cost we were entitled to a reasonable return.

The lower court, after a most ridiculous hearing of the case, apparently decided arbitrarily, without any reasoning whatever, that a certain amount, less than half what we asked for, less than half what we showed we were equitably entitled to, was a reasonable amount. The case went to the Supreme Court of the State of Pennsylvania, which honorable body at the same sitting was able to determine that a two-cent rate per mile for passenger service was not a reasonable return upon the money invested by a railroad for passenger service, but could not see the difference between a 6-inch pipe to furnish fire protection and a $1\frac{1}{2}$-inch pipe, which would be plenty large enough, to supply domestic use. That question will be fought out later. It is a question of vital importance to private water companies, and I think as a matter of good bookkeeping and a just and equitable division of costs, it is a matter of great importance to municipal plants as well, and I am glad that it is emphasized in this paper. I hope that others will have occasion to bring that point to the front, so that the general public will become educated.

Mr. Arthur A. Reimer.* One point on which the writer of the paper touched introduces a question which has been considered somewhat in our city, and I should like to know what the experience of the members is upon it, and that is the question of making one or several charges against several properties under one management or one ownership. That has become quite a live subject with us within the past few weeks. Our plan up to this time has been to make a separate charge for each separate connection, but one party is belaboring us now pretty strongly because we are doing that, and wants us to make one charge on his various properties. I was wondering if any of you have been confronted with such a proposition, and what your solution of the question has been.

Mr. Hawley. Put a meter in each property and charge for each property supplied.

* Superintendent of Water Works, East Orange, N. J.

Mr. Hugh McLean.* This meter question I see, gentlemen, is always with us.

About four or five years ago, when the matter was discussed at length in Boston, practically the same questions came up. At that time I represented the city of Holyoke, and described the adoption of a flat meter rate, that is, water to be sold to all consumers at the same price. One of my reasons for it at that time was that the plan then proposed ought to cure the evil that the last speaker has referred to. The tendency of the times then was for consolidation of interests, and the tendency of the times to-day is the same. By a consolidation of interests, using so much more water, these interests got their water cheaper, thereby lessening the revenue of the department. For instance, at that time we sold water per quarter, I think it was at the rate of 15 cents per 1 000 gallons for the first 50 000 gallons; for all over and above 50 000 up to 200 000 gallons the rate was 10 cents a 1 000 gallons, and for all over and above 200 000 gallons the rate was 5 cents per 1 000. So by the consolidating of interests, such as four or five or as many as twenty concerns joining together under one management, the loss to the department of the benefit in revenue of the maximum rates as charged to each individual concern was equivalent to about $3 000 per year.

There was nothing to prevent the consolidation of other interests, which would lose to the department more of its revenue. I cited at that time, I think, the possible consolidation of the large department stores, whereby inside of each store the elevators might be operated by the elevator company. I suggested the possible consolidation of the landlords' association or the saloon-keepers' association, which could be accomplished just as well as in the case of two of the large industries which I cited as having consolidated.

That situation confronting us, it seemed to me that the claims of many of the citizens that they were entitled to the same rate, they being equal shareholders in the water department with the other taxpayers, had a good deal of justice, and we set out to change the rates and make one uniform rate. As I stated to begin with, the rate, I think, was 15 cents, 10 cents, and 5 cents.

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* Water Commissioner, Holyoke, Mass.

We prepared tables showing what the loss of revenue would be under different ratings. With our engineer and our registrar and superintendent, we finally agreed on a flat uniform rate of $5\frac{2}{3}$ cents per 1 000 gallons, raising it two thirds of a cent above our lowest rate. That increased the rates, I think, to three or four consumers in the entire city, and reduced them to the balance. Our revenue was decreased, however, but slightly, and the system of having one flat uniform rate, the same to all, is working in a very satisfactory manner.

A further result has been in encouraging the introduction of meters, because those who wish to put in meters can buy all of their water at the flat rate; that is very evident. It is working along the lines of decreasing the per capita consumption, as more meters are being installed, and, as I have reason to know, it is lessening our expense for extensions by decreasing the consumption. It is paving the way for a filtration system, whereby we can lay aside some of our surplus to perfect the quality of the water supplied, instead of using it in extensions.

What was said a few minutes ago by Professor Bemis, that it was an injustice either for a public or private water corporation to have different rates, appealed to me. The United States government, as he cited, and as I cited at one of the meetings in Boston some years ago, sells stamps to Wanamaker the same as it does to me. If Wanamaker buys $10 000 worth of stamps, he pays at the same rate that you and I pay. The United States government's tariff is the same on small and large importations. Why should the small user of water have to pay three or four times as much for water as the larger user? I think it is an injustice, and I think we have solved the problem in Holyoke by making a flat rate and placing a rental on the meter. We put the meter into the applicant's premises free, and we charge him a percentage on it which is about 10 per cent., with a minimum of $2 00 per year, or 50 cents a quarter.

Mr. Allen Hazen. Do you charge for the use of the meter in addition to the five cents per 1 000 gallons, or does that cover everything?

Mr. McLean. We charge rental on the meter as already explained.

MR. HAZEN. It seems to me that they are on the right track in Holyoke, Mr. President.

THE PRESIDENT. I have thought so for some time, Mr. Hazen.

MR. McLEAN. The minimum charge is the same to all using the same size of meter. If a mill wants a large meter, which costs a lot of money, we charge them in proportion, — ten per cent. Ten per cent. is our rate for rental, and we keep in repair and renew the meters.

MR. J. H. CHILD. There is one element of service from which, in the way the thing has worked out with us, we are getting no revenue, but from which we should get a revenue, in installing meters. We have a small system and have begun to install meters, first, on the factories and for the large consumers. The practical result of that has been that as soon as we placed the meters, — they had previously paid a flat rate which covered every use of water, the sprinkler heads, and private water hydrants, — the bills went up, in spite of the fact that some time ago we adopted a sliding scale, and some of them got their water for a very low figure. Then they started to drilling wells and eventually cut out almost the entire consumption of water from the water works. They have got an actual money return in their lower insurance rates because of the fact that they have water on their sprinklers at about 140 pounds pressure all the time. Now how to get a proper return for the service is a thing which has been puzzling us. We have in mind a charge of so much per head for the sprinklers, and a lump sum for each hydrant, that charge not to be operative if they use water to an amount that would exceed the minimum charge. I should like to know if that has ever been worked successfully in any other place.

MR. McLEAN. I will state. Mr, President, what I forgot to say when I was on my feet before, that in our city we have a flat charge of $8 a year for hydrants, which the city pays. We charge that as a rental to the fire department for the use of water. We sell water to all of the public buildings the same as we do to individuals, *and we pay taxes to the city* the same as any private corporation. We paid last year $22 000 of taxes into the treasury of the city of Holyoke, which is the equivalent of the levy at the

regular tax-rate on the valuation of our plant. That in my opinion is the proper application of municipal ownership.

THE PRESIDENT. In answer to Mr. Child I should like to state that this question has been pretty thoroughly gone over in this Association in years gone by, and I do not think that as yet any satisfactory solution has ever been arrived at; I never heard of any. At one time a committee was appointed by our Association, including insurance men in its membership, and the committee presented two reports.

MR. CHILD. One of my commissioners is a manufacturer, connected with one of the large plants, and he has told me how the thing works out. One concern, after sprinklers were installed, got a reduction of its insurance from $850 to about $150 a year, the entire cost of the installation of sprinklers being paid for in two years. They are getting the profit of that, and we are getting almost nothing.

MR. ALBERT BLAUVELT.* Mr. President, the subject of how to regulate charges for private fire services, as you know, has been pretty well threshed over, but it may be profitable to take a moment's time to point out why it is that no rule can be devised except to size up the commercial needs of each individual case. A party installing a sprinkler equipment is under no necessity to use the public water system. It does not make any difference where he is located, whether he is in the middle of a prairie or in a town.

Under the rules of the National Fire Protection Association, — which association includes in its membership all classes of insurance bodies, and I am glad to say now includes a great many organizations which are not insurance organizations, and hopes to include water works associations in due time, — a party installing a sprinkler equipment for his private fire protection has two sources of water supply. You can always find out in an individual case what it will cost the plant to put in its second source of supply. That will depend entirely on the magnitude of the plant and the circumstances in connection with the plant. In some cases, perticularly in the West, a second source of water supply can be installed to entirely dispense with the public water service for com-

* Assistant Manager, Western Factory Association, Chicago, Ill.

paratively little money. In some small plants an air-pressure tank can be used, and the entire installation will not cost more than $800 or $900. In some other cases it would be necessary, perhaps, for the party to put in a large water tower or an elevated tank, or he might have to put in a big cistern or reservoir and an underwriters' pump, so that the expense of replacing the city water might run up to $7 500. In a rough way you can say that to dispense with city water for an ordinary protected plant will cost from $1 500 to $3 000, although it might come to only half of that or might come to several times as much. Now, interest, depreciation, and up-keep of that second source of supply, whatever it may be, will always be somewhere between 15 and 20 per cent. The parties owning the property, perhaps, will not admit it, but you all know very well that interest and depreciation and up-keep of any kind of apparatus will never be less than 15 per cent., and in some cases it will be more than 20. So if your party is up against a problem of spending $2 500 to dispense with city water altogether, you can figure that he can afford to pay you somewhere between 15 and 20 per cent. on that amount rather than to put in his private equipment. You will not find any of these plant owners who will admit that the saving in the cost of insurance has anything to do with the case. It is purely a matter of the investment necessary and the amount of the fixed charges which must be met in order to do without the public water works' service, which again can be done in any and all instances.

THE PRESIDENT. I should like to ask Mr. McLean at what size of meter he draws the line for his minimum charge of $2; that is, what is the smallest.

MR. MCLEAN. Three quarters of an inch.

THE PRESIDENT. From that upward do you charge rental at the rate of 10 per cent.?

MR. MCLEAN. Ten per cent.

MR. LEONARD METCALF.* I have been exceedingly interested in listening to the paper and to the discussion which has followed it, particularly to that suggestion of Mr. Richards that the cost of the fire service should be deducted from the cost of the entire

* Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.

service before determining the rates, for it has seemed to me that the tendency to-day in our American cities has been rather in the opposite direction than in the direction of making payment to the water department which should in any way approximate the cost of furnishing hydrant service. I have looked into the question in a few cases, and I never have found a case in which the hydrant rental approached the actual cost of furnishing that service. It seems to me that in the case of Holyoke, for instance, $8 per hydrant cannot cover the cost to the water department for furnishing that service; so I was going to ask the speaker whether the rate of $8 per hydrant was based upon a computation of the cost of furnishing hydrant service; and I would also ask Professor Bemis what their present method of taking care of this matter in Cleveland is.

Mr. McLean. The cost of $8 a hydrant was settled upon between the city and the water department when the agreement to pay the tax rate, that I have referred to, was made. That was before I came on the board. Our engineer, who is here, was a party to that agreement. Previous to that conditions were different; we did not pay any taxes, and we charged the departments a certain amount per year and didn't meter the water. The rate of $8 a hydrant I think was based on something near the cost of installing the hydrants. The agreement was entered into between the city and the water department in consideration of the latter paying a tax, and the former paying for all water used, the same as all other corporations, and the city to pay $8 a year for every hydrant as they were added.

Mr. Metcalf. That is, you are in effect putting upon the water taker the cost of furnishing the hydrant service, that is, the cost in excess of the amount which you are paid?

Mr. McLean. I don't know as it is in excess. As I say, Mr. Tighe can answer that question; the matter was agreed to before I was on the board.

Mr. James L. Tighe.* It was estimated to be the interest on the cost of the hydrant and the cost of installing it, and does not include anything for the water service.

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* City Engineer, Holyoke, Mass.

Professor Bemis. In answering the question which was asked with regard to Cleveland, I would say that some of our states suffer very much from the failure of home rule; we are not allowed to do as we would like by reason of state legislation, and this is true in regard to this particular point. The state law of Ohio absolutely prohibits any municipal water works from charging a cent for any water used for fire protection, public schools, hospitals, or charities. I do not exactly understand what led to the passage of the law, which is quite old, but it prevents our taking any action. However, we have done one or two things in Cleveland which have helped us some. We have metered the hospitals, and schools, and public buildings, and an agreement has been entered into under which it has been left to a prominent judge to arbitrate the question whether we haven't a right to charge for an excessive use in the schools and hospitals and charitable institutions, — that is, whether the state law contemplated an unreasonable use, or contemplated the use of water as a substitute for coal; for instance, in the running of elevators and fans, and for the manufacture of ice in the hospitals. All those uses of water are being enjoyed by the various institutions. And we are hoping, if we get a favorable ruling as to what is "reasonable use," to make the school department pay for any excess over that reasonable use per capita for every child in daily attendance. At the present time the use of water varies from 3 or 4 gallons per day per child in average attendance during the days the schools are in session to 50 gallons per day per child in average attendance. It is less now than it was before we put on meters.

We meet the question of fire protection by having a rate varying according to the size of the service. Parties are not allowed to use water for fire protection unless it is metered, or unless they pay a charge according to the size of the service. That is working very satisfactorily, and has met the approval of the fire underwriters.

The President. It may be interesting to the members to know that in the city I represent * we are allowed to charge $25 a year for the rental of hydrants on our books, but they do not

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* Springfield, Mass.

pay us any money. We are also allowed to furnish the schools and all public buildings, and water for flushing the sewers and watering the streets free. We have that privilege. We get no money whatever out of the municipality. We hope that sometime all that will be changed.

Mr. McLean. Do you pay taxes?

The President. We do not pay any taxes. I think we would prefer to have the same arrangement that they have in Holyoke.

Mr. McLean. I should like to ask Professor Bemis if in his opinion it is not the fairest way to meter all the water for the schools and for the different departments and have them pay, the same as other individuals and large users of water, and then have the water department pay a tax, the same as other corporations?

Professor Bemis. I believe in that most thoroughly. It is not simply taking the money out of one pocket and putting it into the other, but it makes each department more careful of its own expenditures and own wastes. For instance, if each department at Washington had to pay the post office department for its use of the mails, it would be far more careful of waste, even though it all comes out of the government treasury in the end. But if you cannot do that, if the law does not permit that, I think every water-works department should establish a system of book-keeping and publish to the community every year just what each public building and each department costs to the water department. You can often get a very considerable reduction in waste, after you have metered the water, by presenting the matter in a tactful way to those in charge. For example, we have succeeded in having all the public fountains closed at night; before we had meters they were kept running night and day. We found that when there was free use of water in the cemeteries, in our best cemeteries there was more water being used per capita than the same number of people used when living. [Laughter.]

Mr. Frank L. Fuller.* I will say just a word, Mr. President, in regard to the arrangement at Wellesley, Mass. There we consider the meters as a part of the water-works plant, and we have

*Civil Engineer, Boston, Mass., and member of Water Board, Wellesley, Mass.

a minimum rate of $6 which entitles the consumer to 16 000 gallons per year, at the rate of 37½ cents per 1 000 gallons. If they use in excess of that amount the price is $0.25 for the excess. We charge every one the same price, which I think is right. I always have thought that families should not be called upon to pay a higher price for their water, which is an absolute necessity to them, than is paid by those who use water for profit. A good many greenhouse people have thought that they should have water at a less rate, but the rate has always been maintained at the same price for everybody, and I think it gives general satisfaction. The town makes an appropriation for water used in the street sprinkling and for that used in fountains and for the hydrants. The water used in the public buildings is also metered. We do not meter the water used in street sprinkling, but there is an account kept with that by the number of loads of water put upon the streets.

I should like to say just a word in regard to the question which has been raised about the payment of water rates by the landlord. Of course our town is different, I suppose, from the case Mr. Richards spoke about in his paper. We always send the bill to the tenant, and the tenant pays the water rates, the same as he pays his other bills. The landlord has nothing to do with it. I suppose, perhaps, the landlord might be responsible for the water rates, but we have never had a case where the tenant didn't pay. As I remember it, we have only a few cases where one meter would cover several families, and we have endeavored to arrange it so that each tenant has his own meter and is charged for the water he uses the same as any one else.

Mr. H. N. Parker.* I have recently had the pleasure of visiting most of the public water works systems in the state of Kansas, and I was very much surprised to find how generally meters are used throughout the state. As we all know, here in the East the introduction of meters has met with a good deal of opposition, but there it seems to be taken for granted that it is a just and equitable way to sell water, and the town is the exception, I think, which sells water in any other way than by meter. They

*Assistant Hydrographer, United States Geological Survey, Washington, D. C.

have different ways of selling it, but the use of meters is practically universal, and it is only a question of time before all the towns in Kansas will be completely metered.

Mr. W. H. Richards (*by letter*). It is a matter of satisfaction to know that there was no endeavor to controvert the logic of my statements that the only equitable way to sell water is by measure; that the reason for the introduction of meters is equity between customers, and that the charge for water should be based on the cost of supplying the same to the particular party under consideration.

If it costs less to supply a large quantity than a small quantity, then the rate should be less for a large quantity. If a large quantity is drawn through one service pipe, then it costs less. In the case of fire hydrants the quantity of water is comparatively so small as to be negligible, and the cost is in the hydrants and the extra large pipes through which the water is drawn, and they should be so charged for. The same holds good for private fire service.

I agree with Mr. Hawley that a municipal water works stands on the same footing as a private corporation, and further, that the taxpayer has no interest in the water department except in so far as the municipality uses water; and every public use should be paid for on the same terms as a private use.

If, as I understand was the case at Holyoke, all the water used through many different service pipes was grouped together and charged on one bill, then the cost of the service pipes and mains to furnish the supply was neglected, and the reason for a graduated rate was circumvented. If the rules had required the charge to be based on the quantity drawn through *each* service pipe, then the laws of logic and equity would have been satisfied. If the Holyoke water department can supply water at $5\frac{2}{3}$ cents per thousand gallons it has built its system at a very low cost. If it is supplying water in very large quantities to manufactories at the same cost as to residences, it is charging a larger proportion of the cost to one than to the other.

The illustration of the charge for postage is an argument in favor of graduated rates, since the charge for other than first-class matter is less because the service is less valuable, just as water is

less valuable to the manufacturer than to the party using it for domestic purposes.

In reply to Mr. Fuller, it goes without saying that to prevent loss, the water rent should be a lien on the property, and hence the owner is liable; otherwise there is no way of collecting the water rates except by a suit at law for debt, and if two tenants are supplied through one service pipe, to shut off the one who will not pay, necessitates shutting off the one who has paid.

RUBBER PIPE JOINTS.

BY ROBERT SPURR WESTON, SANITARY EXPERT, BOSTON, MASS.

[*Read September 24, 1908.*]

During the past winter in Europe the writer noticed that much water pipe was being jointed with pure rubber rings in place of the customary lead and yard. It is thought that this simple process might be of interest and use to the members of this Association. The process was very simple. The rubber ring was slipped over the spigot end of the pipe, the spigot of this pipe was then forced into the bell of the next pipe by means of a long lever, compressing the rubber between the iron surfaces and making a very tight joint. Clay was then forced into the remaining space and the job was done.

The following information was obtained regarding this method of jointing. To begin with, the "Normal" pipe of the *Verein deutscher Ingenieure* has the form shown in the following sketch (Fig. 1).

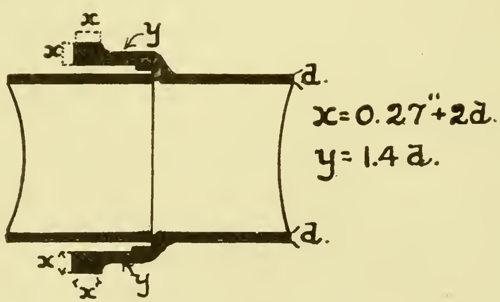

FIG. 1. "NORMAL" CAST-IRON PIPE OF THE VEREIN DEUTSCHER INGENIEURE.

The thickness of the shell of this normal pipe is determined by the formula

$$d = 6.0 + 0.001 \times D \times A = \text{thickness in millimeters.}$$

where

D = inside diameter in millimeters.

A = testing pressure of 20 atmospheres.

The German pipe is made in more sizes than is customary in this country. A few of the dimensions of the "Normal" pipe corresponding to the standard New England Water Works Association pipe diameters, and expressed in equivalent United States units of measure, are given in the following table:

SIZES OF GERMAN "NORMAL" PIPE.

Inside Diameter. Inches.	Diameter. Millimeters.	Outside Diameter, Inches.	Laid Length, Feet.	Diameter of Sockets, Inches.	Depth of Sockets, Inches.	Width of Joint Space, Inches.
4	100	4.65	9.9	5.24	3.46	0.30
6	150	6.69	9.9	7.28	3.70	0.30
8	200	8.75	9.9	9.37	3.94	0.32
10	250	10.78	11.1	11.44	4.05	0.33
12	300	12.82	13.1	13.10	4.13	0.33
14	350	14.88	13.1	15.53	4.21	0.33
16	400	16.89	13.1	17.64	4.33	0.37
18	450	18.90	13.1	19.63	4.41	0.37
20	500	20.93	13.1	21.73	4.53	0.39
24	600	24.97	13.1	25.78	4.72	0.41
30	750	31.10	13.1	31.98	5.00	0.43
36	900	37.20	13.1	38.18	5.31	0.49
48	1,200	49.40	13.1	50.52	5.90	0.51

It will be noted that the "Normal" pipe differs in many particulars from the New England Water Works Association "Standard" pipe, e.g.:

First, there is neither bead on the end of the spigot nor retention spaces for the lead in the bell.

Second, the socket is deeper and there is a shoulder in the bell which serves the purpose of the bead on the New England Water Works Association standard pipe.

Third, the increases in dimensions of socket vary more uniformly with the increase in diameter of the pipe.

Fourth, should the shell of the pipe be thickened, the outside diameter remains constant.

In thickness of shell, the German pipe lies between classes A and B of the New England Water Works Association standards, as the following table will show:

Thickness of Pipes.

"NORMAL" PIPE OF THE VEREIN DEUTSCHER INGENIEURE COMPARED WITH STANDARD PIPE OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

Diameter.		Thickness of Shell. Inches.			
Inches.	Millimeters.	Ver. d. Ing.	N. E. W. W. Assn. Class A.	Class B.	Class C.
4	100	0.35	0.34	....	0.36
6	150	0.39	0.38	....	0.42
8	200	0.43	0.42	....	0.48
10	250	0.47	0.47	0.50	....
12	300	0.51	0.49	0.53	....
14	350	0.55	0.53	0.57	....
16	400	0.57	0.55	0.60	....
18	450	0.59	0.57	0.63	....
20	500	0.63	0.60	0.66	....
24	600	0.67	0.64	0.72	....
30	750	0.79	0.71	0.81	....
36	900	0.89	....	0.90	....

The German pipe is recommended for general use with pressures varying from 60 to 105 pounds per square inch.

Pipe for use with rubber rings should not have the retention space cast in the bell, and the spigot may have a groove 0.2 inch deep to prevent the ring slipping during process of jointing. This groove is sometimes omitted. The pressure which the joint will withstand depends upon the degree of compression, and consequently the holding friction of the rubber ring. The groove permits a thicker ring to be used than is possible without it.

The following sketch (Fig. 2) shows how "Standard" pipe may be adapted for use with rubber rings, and the degree of compression

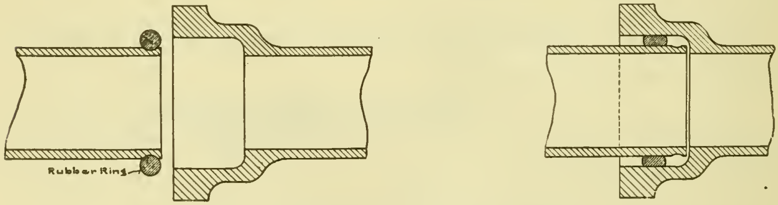

Fig. 2. Method of Jointing Pipes.

to which the ring would be subjected in practice. The thickness of the ring before compression should be twice the width of the joint. The inside diameter of the rings should be somewhat less than the outside diameter of the pipe, that they may be held in place by their own elasticity during the processes of jointing.

The sizes of the rings for pipes of classes A, B, and C would be as follows:

Diameter of Pipe, Inches	Inside Diameter of Ring, Inches.	Thickness of Ring, Inches.	Weight of Ring, Lbs.
4	4.50	0.80	0.136
6	6.50	0.80	0.195
8	8.50	0.80	0.247
10	10.25	0.80	0.294
12	12.25	0.80	0.348
14	14.25	0.80	0.401
16	16.25	1.00	1.437
18	18.00	1.00	1.582
20	20.00	1.00	1.747
24	24.00	1.00	2.081
30	30.00	1.00	2.45
36	36.00	1.00	3.08

The rubber rings used should be of the best pure gum, preferably the variety known as Para gum. They cost from $2.50 to $3 a pound at present prices, and are usually made of pure gum rods, butt-jointed and vulcanized. Their cross section is circular. Rings of hemp coated with rubber have been tried but are not to be recommended because of their low elasticity, upon which the tightness of the joint depends.

The comparative costs per joint of lead and rubber joints may be estimated as follows, assuming lead to cost 5 cents and rubber $3 a pound, and using New England Water Works Association Standard pipe without the retention space:

COMPARATIVE COSTS OF LEAD AND RUBBER PIPE JOINTS.

Diameter of Pipe, In.	Thickness of Joint, In.	Estimated Cost of Lead, Yarn, and Calking.	Cost of Rubber Ring.	Cost of Laying.	Total Cost per Joint. Lead.	Total Cost per Joint. Rubber.
4	0.40	$0.54	$0.48	$0.09	$0.63	$0.57
6	0.40	0.86	0.58	0.12	0.98	0.70
8	0.40	0.97	0.74	0.15	1.12	0.89
10	0.40	1.21	0.88	0.20	1.41	1.08
12	0.40	1.48	1.05	0.24	1.72	1.29
14	0.40	1.78	1.20	0.30	2.08	1.50
16	0.50	2.08	4.31	0.36	2.44	4.67
18	0.50	2.39	4.75	0.42	2.81	5.17
20	0.50	2.68	5.24	0.48	3.16	5.72
24	0.50	3.60	6.25	0.60	4.20	6.85
30	0.50	5.30	7.34	0.90	6.20	8.24
36	0.50	6.51	9.24	1.17	7.68	10.41

It will be noted that up to and including 14-inch pipe the rubber joint is a little cheaper, even without allowing for the cost of bell-holes not needed for jointing with rubber rings. There is no reason why the width of joint for pipe 16 inches in diameter and above could not be reduced to 0.45 inch, or even 0.40 inch, when the cost of rubber joints would be less than that of lead joints, as shown in the following table:

COMPARATIVE COSTS OF LEAD AND RUBBER PIPE JOINTS FOR PIPE 16 INCHES AND OVER IN DIAMETER, HAVING A JOINT SPACE 0.40 INCHES WIDE.

	Cost of Joint.	
Diameter of Pipe, Inches.	Lead.	Rubber.
16	$2.44	$1.89
18	2.81	2.11
20	3.16	2.31
24	4.20	2.82
30	6.20	3.56
36	7.68	4.13

The advantages and disadvantages of the rubber joint may be stated as follows:

One of its chief advantages is that it is extremely flexible. The rubber ring is midway in the bell and therefore at the axis of movement. Therefore no serious unequal compression of the ring can result if the pipe be thrown out of line. The joint is almost perfectly tight and needs no calking; it may, therefore, take the place of flanged pipe for suction mains connecting tube wells. In such cases the position of the branches may be adapted to suit the wells. This is often a great convenience because it is impracticable in all cases to sink wells in exact predetermined positions. Pipe with rubber joints is easier to lay on account of the absence of bell-holes and the simplicity of the jointing tools. There is less breakage of pipe due to settlement of earth. It resists electrolysis most efficiently. The rubber joint, on the other hand, has not been used for high pressures. How much pressure it will withstand could not be ascertained. It is in use in systems which carry 50 pounds pressure, and probably could be used for pressures considerably higher. The joints appear to be durable. If exposed to air, rubber absorbs oxygen, loses its elasticity, and becomes hard and useless. Compressed in a pipe joint, however, it

is preserved. A ring removed after eighteen years of service was apparently as good as new. It would be more durable in contact with ground water than with surface water.

Many German and European supplies are from wells driven in gathering grounds located above the level of the city. In several instances the water is siphoned from the wells to the distributing reservoir by means of rubber-jointed pipe. The proposed new water supply of Prague contemplates such a line from the mountains several miles distant from the city.

This paper is written with the hope that some members of this Association may try these joints and determine their worth under the conditions of American water-works practice. While not at all new, they have not been tried in this country to any great extent. The writer wishes to thank Dr. A. Thiem, C. E., and Mr. A. Lang, C. E., of Leipsic, for information regarding the use of this joint.

DISCUSSION.

The President. Gentlemen, the paper is now open for discussion.

Mr. Allen Hazen.* Mr. President, I had the good fortune to see these joints in use in Germany about fifteen years ago. I think the joints were comparatively novel at the time, and if I remember, in speaking to this Association after my return, I mentioned them. They were used at that time in suction mains. They were used because by their use it was possible to get a line which was perfectly air-tight, and a lead joint, as you know, cannot be maintained air-tight. I gather from what Mr. Weston says that their use has been extended, and the extension certainly is a very interesting fact.

I wonder if Mr. Weston knows if in France and Belgium joints have been made partly of rubber and partly of lead, with the idea of combining some of the advantages of both materials.

Mr. Weston. I haven't heard of joints being made of rubber and lead, but I have heard of joints being made of hemp rings coated with rubber, with lead poured on top. A rubber compound ring, which is very similar to our pipe joint packing, is more water-tight than yarn, of course.

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* Consulting Engineer, New York City.

Mr. Murray Forbes.* In case one of those joints should give out, how are the repairs made? Do they have to pull the pipe apart again?

Mr. Weston. Yes. It is doubtful if rubber joints are practicable where frequent repairs or changes are to be made.

Prof. E. W. Bemis.† Isn't the Standard Oil Company using the Dresser coupling for high pressures of natural gas?

Mr. Weston. I cannot say.

Professor Bemis. They are using it for their distributing system entirely in many cities of the West where the pressures are not as large as 60, — and are down to 40 pounds in some cases, — but I think they are using them in their mains running up from West Virginia where they have 300 to 400 pounds pressure. It is not exactly the same thing, but it is a rubber coupling called the Dresser coupling. I haven't examined it very carefully, but it is on the same principle.

Mr. W. C. Hawley.‡ I might answer the question by saying that there are a great many Dresser couplings used in western Pennsylvania under pressures up to 400 or 500 pounds per square inch for natural gas.

In connection with the matter of pipe joints it may be of interest to members of the Association if I call their attention to a new material, which has come on to the market within two or three years, known as "Leadite," manufactured in Philadelphia. My attention was called to it by a salesman of water-works supplies some two or three years ago, and on his advice I got some of the material and tried it, and I have been using it exclusively now for over two years. It is a mixture of iron filings, sulphur, and silica. It melts at a temperaure considerably lower than lead,— at something like 250° F., I think,—and is poured into the joint in the same way as you pour lead, but it requires no calking. It weighs about one sixth as much as lead and costs about twice as much per pound; therefore per unit of volume it costs one third. The cost of a large bell hole is saved, and the cost of calking, and I believe my joints are costing me from a third to perhaps a half of what lead joints

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* General Manager, Westmoreland Water Co., Greensburg, Penn.

† Superintendent of Water Works, Cleveland, Ohio.

‡ General Manager, Pennsylvania Water Co., Wilkinsburg, Penn.

would cost. The material cools quickly with little shrinkage. I have had no trouble with the shrinkage except in some large 30-inch sleeve joints. Repairs are easily made. The material is rather brittle when it is hard, and with a chisel is easily cut out, and you can run the new part of the joint and it takes a firm hold on the old part; the material seems to take hold of the iron when it is clean. I am using it under pressures up to 200 pounds per square inch, and have had no trouble with any of the joints except where we had a slip on the hillside the other day which took pipe and all, and there a little of the leadite crushed out, where I suppose the whole joint would have gone if it had been lead.

It requires rather careful manipulation, and yet our men have had no difficulty with it. Our man who melts it is an eighteen-year-old Italian, and he thinks there is nothing like leadite now. I understand it is in use in Atlantic City, and I presume Mr. Van Gilder can tell us something about it. A contractor recently told me that he had been laying some 12- and 16-inch pipe through a swamp near Reading, Penn., I believe, and he had found leadite very much better for use in wet ditches than lead; he simply left a hole at the bottom of the joint with the water running out of it and poured the hot stuff in and it closed up the joint, making it tight with very little difficulty. The worst trouble we have had is on account of its catching fire if it gets a little too hot, but it is very easy to put the fire out by throwing a few handfuls of the fresh material on, — it comes in the form of a fine black powder, — and my foreman recently told me he found that a bucket of water would put it out quickly without any serious consequences.

The President. Is Mr Van Gilder in the room?

Mr. Van Gilder.* I do not think I can say anything further as to the use of leadite, except to indorse most heartily what Mr. Hawley has said. We have had no difficulty with it except with one joint, during the two years and a half I have been in this department, and that was in a soft bed under the railroad with very heavy traffic. That is a case where it was impossible to hold a lead joint, and it was impossible to hold a leadite joint because in time it would crumble. We have overcome that since by putting a sleeve over the pipe. We find it to be very superior to lead

*Superintendent of Water Works, Atlantic City, N. J.

in very wet places, for the reason you can pour it in the joint with perfect safety to your men, which would be utterly impossible with lead. We can fill up the joints by pouring in the material quickly, and then we let it chill and it is all done.

MR. HAWLEY. Of course one has to use a much higher " gate " with leadite than with lead, on account of the difference in weight. We make a hollow cylinder of clay, perhaps 6 or 8 inches high, put that over the bell, and pour through that, filling it, and leave it long enough to chill. I think a large joint should be run slowly because there is some shrinkage, just as there is with sulphur.

MR. CHARLES E. CHANDLER.* In connection with rubber joints and air-tight joints for pumping, I will say that there are several miles of cast-iron pipe laid in the city of Norwich, with rubber joints, for transmitting compressed air, which may be of some interest. All of the joints are rubber joints, formed by putting a sleeve over the joint, the pipes not having any bells. A rubber ring goes on each end of the sleeve, and outside of that a double clamp which bolts and squeezes the rubber and makes the joint. The rubber rings are square in section and the clamps are not quite square, so they hug the rubber bands down to the pipe. Those rubber joints can be made just as tight as screwing up the bolts will make them.

The experience there was that after about a year practically all the joints had to be dug up and the bolts tightened. After being in five years, under 90 pounds air pressure, there are a great many leaks. In the center of the city, where brick paving was laid last year, the circumstances are such as to show up the leaks more than ever before, and it is quite interesting to people who go by on the trolley cars. For instance, a leak in the compressed air main in an ordinary street, where there was no paving, unless it was raining, would not show up at all, but when the street was paved with brick the only escape for the air was near the trolley tracks, and when the trolley sprinkler goes along, and there is plenty of water, the pot boils very nicely, and it attracts a great deal of attention.

MR. FRANK L. FULLER. Was that wrought-iron pipe?

* Civil Engineer, Norwich, Conn.

Mr. Chandler. No, sir; it was plain, straight cast-iron pipe without any bells.

Mr. Weston. I might say in connection with the experience that Mr. Chandler has had in Norwich that I think one would expect that any rubber joints in contact with air would become hard in about two years, or less. Rubber, even the best of rubber, will absorb about 25 per cent. of its weight of oxygen in a very short time when exposed to air, and when it does so it changes from what might be called a gum to a gum resin, just as linseed oil changes from an oil to resin, and in doing so becomes brittle and useless for all purposes where elasticity is of value. I think the cases in which we would think of using rubber joints, or the cases where they are particularly applicable, are those in which the rubber can be protected against the action of oxygen, as it can be in a water pipe, where the space on one side, the outside, would be filled with clay, and on the other by the silt which would come from a surface water and protect the joint, and also on the inside by the carbonic acid gas which is always present in a ground water. I would not think that the rubber joints I have described would be applicable for use with air pipes, but I do think it can be used especially for suction pipes in connection with driven-well systems.

Mr. E. S. Saunders. Suppose you had a cracked end and had to cut off the end of a bead end, how would you hold the pipe?

Mr. Weston. I think it would be safer in that case to make a lead joint, or put the lead over the rubber, but in a long line of pipe I think it is perfectly safe to use rubber.

Mr. Chandler. I suppose it might be proper to say that in France, where they use a great deal of compressed air, they use the rubber joints. Perhaps some one here can tell us whether those air pipes are laid in subways, where they are accessible for repairing the joints. I do not know whether that is the case, but the idea of using rubber joints for compressed air came from the fact that they are used in France. These joints I speak of, of course, have very slight contact with the air. We have the sleeve over the joint and the rubber on the outer end of the sleeve, and the opportunity for air to get to the joint is very slight, but of course it can get there.

Mr. Weston. As I remember, some European rubber joints are made with ordinary flanges and they require packing. I have seen very few cases however.

Mr. Chandler. Flanged pipes?

Mr. Weston. Regular flanged pipes.

Mr. Chandler. I didn't think so, but it may be so. The joint I speak of gives flexibility, which of course a flanged joint would not have.

Mr. M. N. Baker. Those interested in the use of leadite for pipe joints can find a considerable amount of further information on the subject in the proceedings of the American Water Works Association for the present year. The consensus of opinion on the part of those who spoke on this material, so far as I remember, was very favorable to it.

Mr. Weston. A recent letter from a German friend states that rubber rings are not being used in general practice for jointing pipes beneath paved streets or where pressures are very high. In such cases, lead and yarn joints are more economical. For work inside of buildings where pressures are high, rubber joints with the rings secured in place by means of an iron ring clamped to the pipe described by Mr. Chandler have been used in place of flanged joints, thereby gaining much flexibility. The new use which is being made of rubber joints is for long mains leading from wells or other gathering grounds across hills and valleys, under vacuum and pressure, to pumping stations or cities. In these cases the superior tightness of a rubber joint outweighs most disadvantages.

Mr. Will J. Sando. (By letter.) The rubber ring joint has been used between faced flanges inserted in a wedge-shaped groove a great many years with good success.

The sketch by Mr. Weston shows that the rubber makes a parallel joint between the inside of the bell and the outside of the spigot, and the tightness is dependent on the friction of the rubber and metal. In this form it might be blown out by the pressure of the water inside of the pipe. This might easily cause trouble and be very expensive in repairs.

The accompanying sketch (Fig. 3) shows, I believe, a more reliable form of this same joint. It is made by tapering the outside of the spigot end so that the rubber ring will tighten more as it is

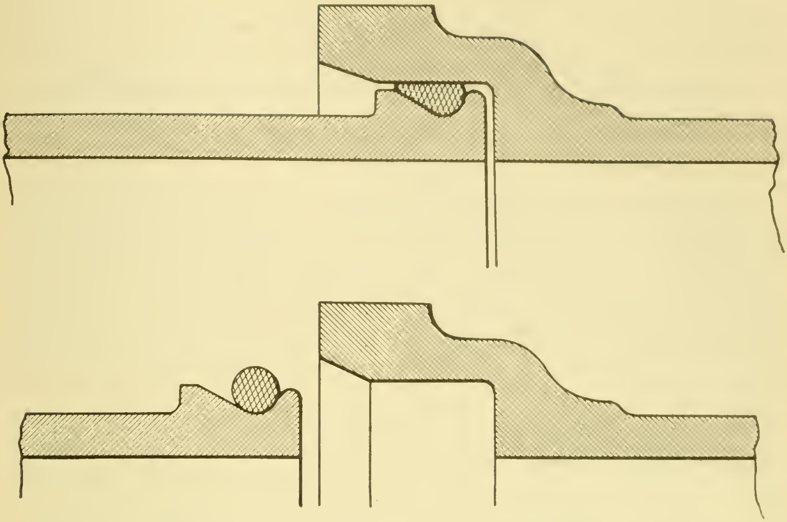

FIG. 3. RUBBER PIPE JOINT AS SUGGESTED BY WILL J. SANDO.

inserted into the bell end and then any additional pressure from the water inside will also tend to make the joint tighter. It seems to me there are places where a joint made in this manner could be used to good advantage.

INSURANCE RATES AND THE WATER SERVICE.

BY FRANK A. BARBOUR, CIVIL ENGINEER, BOSTON, MASS.

[*Read September 24, 1908.*]

Some recent work involving the betterment of the existing water works in several cities and towns, and the fact that, following these improvements, reductions in the insurance rates were granted by the underwriters, has suggested to the writer that a very brief description of the work done, in so far as it affected the fire service and a statement of the reductions allowed, might be of interest to this Association.

It may be possible that in some communities the logical results of such improvements have not been obtained — either through civic inertia or through failure to appreciate the opportunity, — and that the experiences herein described may prove profitably suggestive.

IMPROVEMENT OF ST. JOHN WATER SUPPLY.

In 1905, the development of a new water supply for the city of St. John, N. B., was undertaken, the work involving the extension of the then existing pipe lines from a point about 5 miles distant from the city to a more distant source, at an elevation 138 feet higher than the old supply. The pipe lines to the city included two 24-inch cast-iron pipes, one laid in 1857, the other in 1873, and a 12-inch cast-iron pipe laid in 1851. The distribution system, which was generally of equal or greater age (some of the pipes having been laid as early as 1837), was fairly adequate in size, requiring for efficient fire service additional pressure rather than enlargement of pipe diameters.

The extension of the works to the new supply included 10 000 feet of 33-inch wood stave pipe, 7 500 feet of 39-inch reinforced concrete conduit, laid about 20 feet below the hydraulic grade line and ending in a lake of 600 000 gallons capacity, but with small watershed, from which lake a 48-inch reinforced concrete conduit, 6 200 feet in length, laid partly in tunnel and partly in open cut, connected with the main source of supply, the Mispec

River where a concrete dam was constructed. The total expenditure (not including a pulp mill, purchased in order to avoid damages for diversion of water, which should yield an amount in rental equal to its cost), was about $300 000.

The topography of the city is most irregular, surface elevations varying as much as 125 feet, the higher areas being within 40 feet of the surface of the old supply. Previous to the installation of the new works the system had been divided into a high and low service, the water for the former being lifted by turbine and power pump 35 feet higher than the elevation possible by gravity. Under the present system the city is supplied in a single service, the pipes working in common with full pressure on the mains to the city limits, where two Ross regulating valves are installed by which the pressure is reduced some 15 pounds or to the point where it will drop by friction loss in the mains under an extreme fire draft. In this way the distribution system is relieved of the full static pressure without detriment to the fire service.

The application of the higher pressure to a system of such age was a matter of considerable responsibility and one demanding great care and patience. It was out of the question to undertake a general replacement of the system, as this was beyond the financial capacity of the city. The proof of the ability of the 24-inch mains to meet the new conditions could only be made by actual hydraulic tests in the ground. Examination of individual pipes, while indicating the iron to be of good quality and of the necessary thickness, was of relatively small value, as the breaks would occur in pipes weaker than the average. It was, therefore, decided, to supply the city through one of the 24-inch lines and to test the other main by gradually stepping up the pressure, repairing such breaks as occurred with each increment, and finally applying 20 pounds in excess of the full static pressure of the new supply by developing water-hammer through the operation of blow-off valves. After the weak pipes in the first main were eliminated in this way, this conduit was thrown into service and similar work done with the other main. The 12-inch pipe laid in 1851 was abandoned as of little or no value. When the full pressure of 110 pounds had been applied to both mains, the pressure in the distribution system was gradually increased by manipulating the regulating valves.

By the installation of these new works the pressure throughout the city was increased about 40 pounds, and from four to ten good direct fire streams, the number depending on the variation in surface levels, were made possible, while with engines from ten to twenty streams were obtained. As the commercial center is generally in the lower areas, the possibility of direct service is of great value, especially in a city where the efficiency of the fire department is not up to the metropolitan standard. With the old pipe lines, not more than two direct streams were possible and the maximum draft with engines was probably not more than 2 000 gallons per minute.

RESULTING SAVING IN INSURANCE.

As a result of these improvements a reduction in the insurance rate of 25 cents has been granted on mercantile property, the total yearly amount somewhat exceeding $30 000, which is more than double the interest cost of the entire improvements.

NOTES ON OLD PIPES AT ST. JOHN.

A few notes on the work in St. John in connection with the old pipe lines may be of interest. The pipes in the first 24-inch line, laid in 1857, have a thickness of about three quarters of an inch. The exterior surface shows no signs of having been coated; neither does it show any serious corrosion, the iron when broken being good to the extreme outer edge. About one sixteenth of an inch of the interior surface is black and easily abraded. The pipe is badly incrusted, although it has been cleaned several times in past years by the method used in St. John and Halifax, and already described in a paper read before this Association by the superintendent of the St. John system.* The joints were made of white pine and are in good condition, without leakage under the heavier pressure, except in some places where the key-wedges were badly fitted. A section of this pipe, 3 600 feet long, laid through marsh mud at tide level, was found to be badly disintegrated and was replaced. In many instances it was possible to cut the pipe with a knife through a considerable portion of its thickness. The new

* Journal of the New England Water Works Association, Vol. XIII, p. 147 (December, 1898).

cast-iron pipe was embedded and wrapped with a layer of clay, since such sections of the old pipe as had been laid in this material have apparently escaped any disintegrating effect of the tidal mud. Pipe laid in sand at about the same level was not affected, and of twenty-one lengths, each 9 feet long and weighing 2 300 pounds per length, only one broke.

The pipe laid in 1873 was of two classes: one, seven eights of an inch thick, and the other one inch thick. The pipe was coated and is in better condition than the pipe laid at the earlier dates. In this line four types of joints were employed: first, a turned and bored joint; second, a turned and bored joint made up with lead and a strap to hold the lead in place; third, a wood-stave joint, and fourth the ordinary lead joint.

In the distribution system relatively few breaks have occurred, although in some cases the pressure is 95 pounds per square inch. The pipes which have been broken have usually been thin on one side, presumably the result of having been cast horizontally. The service pipe was not tapped but driven into the main, with a keeper which extends around the pipe. Local plumbers predicted that these connections would be blown out by the heavier pressure, but only one such case has occurred.

Precise instruments have not been available for the determination of the friction loss in those old mains, but from gage readings and measurements of the discharge by Venturi meters, it appears that the coefficient C in the Chezy formula, practically applicable to these mains, is between 65 and 70, the factor of leakage from the pipes between points of gaging discounting any attempt at greater accuracy.

The gradual stepping up of the pressure on the distribution system by the use of the regulating valves and measurements of the flow by Venturi meters indicated an increase in leakage from the distribution system about 5 per cent. greater than in direct ratio to the square root of the pressure. This leakage, while not of serious moment in the present instance where the supply is ample and obtained by gravity, would, in the case of a pumping system, be as great a factor in the depreciation of the old mains as the actual strength of the pipe. In an endeavor to determine the ocation of abnormal leakage the pipe system is being tested in small

districts between the hours of 12 midnight and 4 A.M. by shutting connections to the section under examination and supplying it with water through a meter set in a hose line stretched from a hydrant outside to a hydrant inside the district. Street after street is then shut off and the effect on the meter noted. Gates are sounded for leakage by the aquaphone, and as an additional check a small meter is placed on some sill-cock and water run through it for a certain length of time. If the water in hose line indicates an equal discharge it is concluded that all water entering the district is being measured. Leakage is an element of interest in insurance rating because of its effect in reducing pressures in the distribution system and may become of serious moment when large in proportion to the legitimate consumption.

IMPROVEMENT OF THE FREDERICTON WATER SUPPLY.

The city of Fredericton, N. B., was supplied by pumping direct into the mains without elevated storage, the pumps necessarily running twenty-four hours. In connection with the installation of a mechanical filtration plant recently constructed, a clear water well of 400 000 gallons capacity was provided, largely as a fire reserve, and the old pump of 1 500 gallons per minute capacity was reinforced by new apparatus of double this discharge. In time of fire a pressure of 80 pounds is maintained at the station, but the effective pressure at the hydrant is considerably less owing to an inadequate distribution system, twenty-four years old, and much incrusted by the action of the river water on the pipes.

RESULTING SAVING IN INSURANCE.

As a result of the installation of the larger pump a reduction in the insurance rate has been made equal in yearly total to about $6 000, or practically three times the interest on cost of the improvements chargeable to fire protection.

IMPROVEMENT OF THE ATTLEBORO WATER SUPPLY.

In Attleboro, Mass., previous to 1904, the principal elements of the distribution system were a single main between the pumping station and the town, and a steel standpipe of 660 000 gallons capacity, with its water surface, when full, 140 feet above the level

of the business center. This standpipe held the night's supply, but in case of fire, owing to inadequate elevation, it was shut off from the system by the closing of a gate and the pressure then obtained direct by starting up the pumps. Improvements carried out between 1904 and 1906 included the construction of a reinforced concrete standpipe of 1 500 000 gallons capacity, with its top 100 feet higher than that of the old standpipe; the laying of a second main between the pumping station and the point of storage, and of a larger main from this latter point to the center of consumption. Under the old system of direct pressure in time of fire the maximum service was six streams with 65 pounds at the hydrant. The new standpipe is of such capacity and height that assuming a sixteen-hour shut-down of the pumps, the storage reduced during this period by the estimated consumption twenty years hence and a fire occurring at the end of the sixteen hours, fifteen streams with 65 pounds at the hydrant can be maintained for one hour without starting up the pumps. In a test made in 1906, sixteen streams discharging 3 800 gallons per minute were shown with a pressure at the hydrant of 75 pounds. *As a result of these improvements a 10 per cent. reduction of the mercantile rate of insurance was allowed by the underwriters.*

GENERAL CONSIDERATIONS.

The three preceding instances of reduction in the insurance rates as a result of improvements of the water service illustrate the value accorded by the underwriters to increased pressure in a gravity system, greater pumping capacity in a direct pressure system, and larger storage and the duplication of mains in a pumping system with standpipe. The amounts of the reductions were determined by committees representing underwriting associations — in two cases as a result of applications made by the municipal authorities after the work was completed, and in this third case, that of St. John, N. B., as a reward promised before the improvements were undertaken. It is safe to say that in none of these cases was there any attempt to estimate the value of the improvements in reducing the fire hazard on any definite basis derived by experiences and made applicable by records of fire losses relative to the character of the water service. It would seem, however, that the

time must soon arrive when such logical proportioning of rates to the factors controlling fire hazards will be possible.

It is true that the water service is only one element in a very complex problem; that the character of building construction and the efficiency of the fire department are of almost or quite equal importance, and that the basic rate applicable to any city must be a product of several factors, each subject to modification as made necessary by the local conditions. With due appreciation, however, of the complexity of the problem, it is believed that a more logical co-relation of the character of the water service and the fire hazard can be developed. The possibility lies in the extension of schedule rating by which rates will be scientifically developed from the accumulated experience of underwriting associations in such a way as to gradually eliminate the personal equation and the discrepancy now existing in the assessment of individual risks. In such rating the proportionate effect of the water service would be determined and the relative value of works of different character made known to municipal authorities.

The ultimate end of insurance associations is not merely the payment of losses; another and most important factor is the work which has been done toward the reduction of the fire hazard by investigations, inspections, and insistence on certain standards of construction and fire fighting facilities. From the standpoint of the insurance company, prevention of conflagrations is a better means of profit than high rates, a result proved by the success of the factory mutuals in which the primary motive is the prevention of fires by the provision of specified standards of construction and facilities for preventing conflagrations. In these companies, rates are scheduled, disabilities penalized, and improvements rewarded with definite financial returns. And it is probable that, as schedule rating, scientifically deduced from the accumulated experiences of many companies and developed by some central controlling board of underwriters, becomes the rule, methods approximating those of the above-mentioned companies will be made applicable to general insurance, in which case deficiencies existing in the different municipal departments which have a controlling influence on the conflagration hazards will be definitely expressed as penalties in increased rates which, by certain improvements, can be removed.

As an illustration of schedule rating brief reference may be made to the Universal Mercantile Schedule developed in 1893 which, in some parts of the country, constitutes the principal basis of rating at the present time. By this schedule a key-rate was to be given each city and town, differing in each as was made necessary by local conditions. These key-rates were to be modified for individual risks in accordance with the variations in construction, occupancy, and other particular hazards; and as a basis for the establishment of the key-rates a standard building in a standard city, with gravity water works, adequate distribution system, efficient fire department, and other attributes, was conceived, and for such a building in such an environment a basic rate was adopted from which the key-rates of other cities might be obtained by additions made for certain deficiencies. This schedule was by no means perfect, and has been criticised in several particulars, but for the present purpose it serves to indicate the possibility of schedule rating and the advantage of definitely making known to each community its standing in the rating problem, its deficiencies and the penalties exacted, and finally the improvements necessary to obtain the basic rate of the ideal city. Under such a method, definite incentives to improved standards in the water service, fire department and building construction are presented by the resulting reduction in rates often made possible of attainment without increased cost to the community. And beyond all this, in broader outlook, there is the possibility that by such co-operation of municipal authorities and underwriting associations a long step would be taken toward the actual conservation of property values by lessening the fire losses, which the payments of insurance never can make good, and which, at the present time, in this country, equal ten times the losses in Europe in amount per capita.

DISCUSSION.

The President. Mr. Barbour's paper is now before you for discussion.

Mr. Charles E. Chandler.* I have been very much interested in Mr. Barbour's paper, and as discussion is perhaps best

* Civil Engineer, Norwich, Conn.

induced by some people taking the opposite side, I would say that, having occasion as chairman of a committee of the Connecticut State Board of Trade to meet insurance men comparatively recently, since the San Francisco fire, I take considerable interest in fire insurance. You remember that fire insurance rates, especially on mercantile property, were very largely increased a year or two before the San Francisco fire, and when that fire occurred the merchants and others had just got reconciled to those increased rates. Then the San Francisco fire stampeded the insurance companies, and they immediately made a large raise, 20 cents a hundred, in mercantile rates in what they called conflagration areas. That naturally raised a storm of protest, and committees were appointed from all sorts of trade organizations to treat with the insurance people. The result of it, or at least these committees claimed the result of it, was, that the companies dropped the 20 cents within a short time. They dropped it anyway, whatever the reason was, and perhaps they felt that they had made a mistake in having put it on at all.

But it seemed to be developed by conferences with the representatives of insurance companies that they had an idea that the fear of punishment was a better incentive to improvement in fire service than the hope of reward; at least it seemed as though that was the incentive they used generally. It also appeared that the idea of establishing rates on the principle of putting on all the traffic would bear was very generally followed. They admitted to us that Connecticut was one of the best states in New England in their past experience, that they derived more profit relatively from Connecticut than any other New England state, and when asked if we in Connecticut got better rates than they did in some other places, like Maine, for instance, they said, "We couldn't do business in Maine if we charged them as much as we charge you." [Laughter.]

Mr. Allen Hazen.* It seems to me that this question of fire protection and insurance rates is one that will solve itself in our cities during the next generation. The solution will come by the adoption of better methods of building. Concrete masonry floors will take the place of the wooden floors that are so com-

* Of Hazen & Whipple, Consulting Engineers, New York City.

monly used at the present time, and the change already beginning is bound to go on at an accelerated rate. This change and other improvements in building methods will bring us to the condition which has already been reached in some European cities, where the fire risk is so slight that it is not worth while to insure buildings and it is not worth while to lay the pipes of the water-works system larger than would otherwise be needed, in order to provide fire protection. In other words, the pipes are provided simply for the distribution of the water for domestic purposes and not for its concentration in large quantities on fires. This condition is bound to prevail ultimately with us, and it may come sooner than we now think. In the meantime, we have thousands of wooden buildings and buildings with wooden floors in all of our cities, and we must take care of them, for we cannot afford to lose them now, and while they last provision must be made for concentrating large quantities of water upon the fires that will inevitably take place in them, in order to prevent the spread of those fires with the destructive results which have been experienced too frequently by our cities.

The cost of providing the pipes and facilities for supplying this water from time to time in large quantities is very great. Some one must pay for it, and I believe that the more the expense of doing it can be put upon that class of buildings for which it is alone necessary, and the more that can be done to relieve from the tax the buildings that are fireproof, or substantially so, and do not profit by the service, the better it will be for the water departments and for our cities.

President Martin. I think when that time comes, Mr. Hazen, the school department of the city of Springfield, Mass., will throw up both its hands and require us to furnish all the water we can furnish for running motors. They advance the argument now that we have plenty of water standing idle in the pipes, and say, "Nobody wants it, why can't we use it?"

Mr. Leonard Metcalf.* It seems to me that the remarks of Mr. Chandler but give point to some of the suggestions which Mr. Barbour has made as to the responsibility of water works officials to see to it that the ball is started rolling in the effort to get re-

* Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.

duced insurance rates after radical improvement of the fire protection service. One of the difficulties, of course, in obtaining recognition from the city — the different departments of the city — for the benefit of the water department comes about from the intrusion of politics into the management of city affairs, and also from the desire of the different departments to make as good a showing as they can, so the water department has to bear the burden of making the improvements without getting corresponding recognition. The reduction in the insurance rates unfortunately does not go back to the city treasury nor to the water department, but to the individual, and so perhaps naturally it comes about that the water department postpones making improvements, which it recognizes should be made under existing conditions, in any particular city, until such times as the rates will enable them to do it, although they recognize perfectly well that the improvement should be made and that the saving in insurance rates would largely exceed the interest and other charges of the improvement.

Along this line I have been much interested in two or three cases which have come to my personal notice, following upon the taking of the water companies' property in certain places in Maine, in which water districts had been formed and the properties of the local companies taken over. In several of those cases, at least, the works have been virtually rebuilt, larger mains have been put in, and the fire service has been very materially improved. In some cases there has followed a reduction in the insurance rates. In those cases, under the Maine law, the department is operated as any corporation would be, independent of the city, the revenues being derived from the rates. But the city itself has not availed itself of the opportunity to get improved fire service by the placing of additional hydrants upon the system. In one case, for instance, at Waterville, Me., I remember we recommended that, owing to the distance apart of the hydrants, something like fifty hydrants be placed upon the existing and the new mains, at a nominal cost to the city. The result was, as I remember it, that they placed at first six hydrants and subsequently three more. As a matter of fact, the entire expense of the improvement was caused by the recognition of the fire district

trustees of their responsibility in the matter — their responsibility to furnish the city with a proper fire service — and yet the city officials, or the city council, was not willing to recognize the work to the extent of availing itself of the improved service. This difficulty has been obviated in some measure by offering, for a certain small nominal increase in rental, to place any number of additional hydrants which the city might desire upon existing mains, at the bare cost of placing them there. That perhaps is one step in advance of the old condition, but it is not a fair recognition of the work which the water department has done. I should suppose that competitive conditions in insurance would tend to bring about a reduction in insurance rates after an improvement of the service, but Mr. Chandler's remarks give point to the fact that even that influence does not always work.

THE ADJUSTMENT OF DIVERSION DAMAGES BY STORAGE COMPENSATION.

BY ROBERT E. HORTON, HYDRAULIC ENGINEER, ALBANY, N. Y.

[*Read September 24, 1908.*]

DEFINITION.

Storage compensation, or "compensation in kind," may be defined as regulation of the flow of a stream in such a manner as to compensate for water diverted, by drafts from storage during dry times, in such a manner that the flow of the stream shall never fall below a certain minimum fixed by agreement or adjudication. Such compensation would be furnished in lieu of, or in addition to, money damages for the diversion of water.

ENGLISH PRACTICE.

Compensation in kind apparently originated in England, although I have been unable to find the place or date of its origin. Clemens Herschel, who has given much study to the matter, says that for a hundred years or more this has been and yet is the accepted method in Great Britain. In England the use of compensation in kind in lieu of money damages may be determined upon by an act of Parliament in any case. The act, or a Parliamentary commission sitting as a court, fixes the rate of compensation as some fraction of the available flow. It is customary to deduct one sixth from the total yield of the stream to allow for freshet flow, which it is impracticable to store or utilize. The remaining five sixths is considered as the available flow, and the conditions of compensation require that the stream shall be so regulated that the flow shall at no time be less than a given fraction of the available flow. Humber says: "Mills are never designed to utilize the whole of the water flowing down a stream; by far the larger portion runs to waste, partly in times of excessive rain, and partly when the mills are not at work. The proportion of water utilized necessarily varies in different cases, and it is upon

this point that most of the contention between the promoters of water works and the owners of mills arises. It is ordinarily found that mills are capable of using only from one fourth to one third [of the available flow], and one or other of these proportions, mostly the latter, is generally assigned as the quantity to be passed uniformly and constantly down the stream as compensation." In a characteristic manner the English have reduced this matter to simple but rather arbitrary rule. English practice in compensation varies somewhat from the one-third rule, however, as illustrated by the following examples, collected from Tudsbury and Brightmore's "Water Supply Engineering":

City.	Stream.	Rate.	Date.	Remarks.
Liverpool	Vyrnwy	One-quarter	....	Industries unimportant
,, ...	Rivington	One-half	1847	
,, ...	,,	About one-third	1868	Reduced by purchase
Manchester...	Longendale	Two-fifths	1848	Important industries
,, ...	,,	One-third	1854	Reduced by purchase
,, ...	Thirlmere	About one-tenth	1879	

It will be noted that in two cases the original compensation rate has been subsequently reduced by purchase because the drainage basin was incapable of supplying both demands in full; thus the prime object of compensation in kind has been in some degree nullified.

Obviously there can be no uniform basis for compensation in kind that is applicable to all streams and which is just. The basis and method of compensation should differ according to the variability of the stream, the cost of storage development, the amount of storage which it is feasible to develop, the extent and character of the power development, and the amount of diversion to be made. The general principle may be laid down that for each business and water-power site there is some particular size of development that will yield a larger return per dollar invested than any other size. Any development that does not exceed this limit is a reasonable development, and the basis of compensation should be such as to do it no injury, even though it may require a higher basis of compensation than any other power on the stream.

DIFFICULTY IN EMPLOYING "COMPENSATION IN KIND" IN THE UNITED STATES.

The reason why compensation in kind cannot be made a legal remedy in the United States is that, under the Constitution, property cannot be taken without just compensation, and the United States Supreme Court has ruled that just compensation can only be measured and properly rendered in money.

I do not want to be understood as favoring the compulsory acceptance of compensation in kind as a legal remedy for diversion. There is little doubt that its adoption in this country on the same basis as in England would work a grievous injury to one of our greatest natural resources, — water power.

I believe that compensation in kind by mutual agreement is in some cases the best and cheapest method of adjusting diversion damages. If a prospective water supply would only injure a single riparian owner, it would more often be possible to adjust diversion damages by storage. It is usually the case, however, that a number of mill owners with a wide diversity of interests are to be dealt with, and the real difficulty is to secure concerted action among them. The same difficulty arises in the development of storage, in attempts to substitute central power stations for the wasteful system of distribution of power by hydraulic canals in the old mill towns, and in the development of irrigation and drainage projects. In the case of the two last named, legislation has been adopted in many states by which the will of the majority rules the community as a unit in the execution of such works. If legislation is adopted whereby all may be compelled to join in projects for the regulation of streams by which all will be benefited, a legal difficulty in the way of equitable adjustment of damages by stream diversion will be removed.

Frizell, in his "Treatise on Water Power" (pp. 539–540), suggests a form of law such that no one should be compelled to join in a storage project, but any one failing to pay for such storage should be required to pass down stream unused a quantity of water equal in amount to that fed into the stream from storage.

Such a law would aid to secure the coöperation of such persons as will, under present conditions, hold off in hope of securing the

benefit without payment; and who also, in case of diversion, might secure money damages and at the same time benefit by the compensation reservoirs built to indemnify their less swinish neighbors.

THE NEWTON, N. J., CASE.

In this case, as described by Mr. Louis L. Tribus, a lake was raised 5 feet and the mills were given full control of the resulting storage. They did not release the parties making the diversion, however, and although benefiting by storage and suffering no actual reduction in their power, they brought suit to recover for the diversion made. The court awarded damages of $3 302 for 2.65 continuous horse-power in one case, and $2 650 for 2.54 continuous horse-power in another case. These awards were made on the basis of capitalized cost of substituting steam-power. The higher court reduced the awards to $500 for 2.54 horse-power and $750 for 2.65 horse-power, the new awards being based on the difference in the value of the property before and after the diversion.

Clemens Herschel states that compensation reservoirs were actually built about sixty years ago in connection with the first Cochituate water works of Boston, but could not be used under American laws. I presume that there are other instances where compensation in kind has been used or attempted in this country to which my attention has not been called, and I believe those having the data of such cases should place them on record before this Association.

AN EAST CANADA CREEK CASE.

Power is developed at Beardsley Falls, on East Canada Creek, N. Y., under a head of about 120 feet. The city of Little Falls derives its water supply in part from Spruce Creek, a tributary entering East Canada Creek several miles above the power plant. After considerable litigation the matter of diversion damages was settled out of court, the writer being consultant to the power interest.

The city is allowed to take water from Spruce Creek without restriction upon condition that it shall perpetually pass down stream from its storage reservoir at Salisbury a depth of 3½ inches

at least, on a weir 18 feet long. This corresponds to 9.36 c. f. s. The intention was to provide an ultimate water supply of 6 000 000 gallons per twenty-four hours for the city, which also amounts to

Map showing Compensation Reservoirs on Black River.

about 9.36 c. f. s. The tributary drainage basin of Spruce Creek is 36.2 square miles.

COMPENSATION IN KIND ON BLACK RIVER, N. Y.

The summit level of Erie Canal at Rome is about 25 miles south of the point where the Black River emerges from the southwest slope of the Adirondacks. Black River Canal extends northerly from Rome, connecting the Erie Canal with the navigable portion of Black River below Lyons Falls. Black River Canal also serves as an important feeder of the Erie summit level, supplying it with water diverted from Black River at Boonville. The geographical relations are shown on the accompanying sketch map (page 338).

There are numerous water powers along Black River from Carthage to its mouth, many of which were in use before the original diversion was made in 1849. The Boonville feeder was constructed to carry 267 c. f. s., but the natural minimum flow of the river at Forestport, which is the point of diversion, is only about 117 c. f. s., and during dry times, before the reservoirs subsequently described were constructed, practically the entire flow was diverted. Part of the diversion passes northward, supplying Black River Canal from Boonville to Lyons Falls, where it again enters Black River, and the remainder is permanently diverted, passing southward through Black River Canal and entering the Erie Canal at Rome. As soon as the Boonville feeder was put in use, complaints arose from mill owners, and claims for damages were filed. Part of Black River was, however, a navigable stream and a part of the state canal system, and the question arose and has never been decided, whether the state might not have taken such waters as it needed for navigation purposes without being held liable for damages. Precedent indicated that remuneration might only be obtained through the legislature. It was clearly the policy of the state to protect the industries along its canals, and accordingly Chapter 181 of the Laws of 1851 was enacted, providing for examinations of reservoir sites on Black, Beaver, and Moose rivers, directing the construction of, and appropriating money for, "reservoirs of sufficient capacity to supply the Black River Canal feeder with such quantity of water during the summer months as shall be necessary for the supply of Black River and Erie canals, and as shall give to the Black River, as near as may be, as much water as ordinarily flows therein during the summer months."

Apparently this basis of adjustment was quite satisfactory to a

majority of the riparian owners, although the delays incident to carrying out the provisions of the law caused further trouble. While I have seen no record to that effect, I have reason to believe that this act was drawn at the instance of the riparian owners, and to meet their wishes, and that this mode of compensation was not forced upon them.

The first reservoir was not completed until ten years after the feeder was put in use. Other reservoirs have been completed from time to time, the system at present being as shown in the subjoined table.

STORAGE AND COMPENSATION RESERVOIRS ON BLACK, BEAVER, AND MOOSE RIVERS.

Number on Map.	Name.	Tributary Area, Square Miles.	Approximate Storage Capacity, Cu. Ft.
	BLACK RIVER.		
1	Forestport Pond	86.46 (*a*)	13 068 000
2	„ Reservoir	106.48 (*b*)	213 444 000
3	North Lake	27.76	301 653 000
4	South Lake	5.97	421 312 000
5	Twin Lake	4.77	68 607 000
6	Canachagala Lake	2.08	139 392 000
	WOODHULL CREEK.		
7	Woodhull Lake	9.40	876 601 000
8	Sand Lake	3.00	239 928 000
9	Chub Lake	9.87	34 848 000
	MOOSE RIVER.		
	Fulton Chain of Lakes.		
10	1st to 5th	35.23	352 000 000
11	6th to 7th	17.78	300 000 000
	BEAVER RIVER.		
12	Beaver	153.00	900 000 000
	Total	461.80	3 860 853 000

(*a*) Woodhull Creek, not including Black River.
(*b*) Not including Woodhull Creek.

The present average diversion, taken from the mean of many measurements, is as follows:

Flow in feeder, near mouth	298 c. f. s.
Northward flow, returned to river	79 „
Southward flow, diverted	205 „

This apparently is a notable instance of compensation in kind on an unusually large scale, and comprising some peculiar features.

Two sets of reservoirs are provided, one to increase the supply that may be diverted, to an amount greater than the minimum flow; the other set for compensation. Originally the control of all the reservoirs was vested in the Canal Commissioners, but in 1896 a law was passed giving a commission of three water-power users complete control of all compensation reservoirs.

The law of 1851 failed to specify how many reservoirs should be constructed. The natural result has been a continued struggle on the part of the mill owners to have the reservoir system extended. It appears, however, that not until recently has the reservoir system been adequate to comply with the requirements of the law. No reliable gagings were made in the early years to determine the low-water flow, and the water-power users have been disposed to magnify its amount. It has been commonly reported among the riparian owners that the minimum flow in the vicinity of Watertown is 2 000 c. f. s. I have conducted careful gagings of the stream for several years which show several low-water periods with a flow of only 800 to 1 000 c. f. s., with the reservoirs in operation.

A practical difficulty with so large a system lies in the necessity of placing some of the reservoirs at a distance from the point of diversion. In this case some of the reservoirs are on the Moose and Beaver rivers, tributaries that enter Black River at a distance below Forestport, and there is left an intermediate reach of the river on which there are some water powers that suffer the full effect of diversion and receive little compensation water.

A NEW TYPE OF COMPENSATION IN KIND.

Diversion from West Canada Creek for the water supply of the city of Utica is compensated under contracts with the Utica Gas and Electric Company, owners of the Trenton Falls power plant, and the International Paper Company, which controls the so-called Herkimer hydraulic canal. These are the largest water-power users on the stream, the development being as follows:

	Drainage Area, Sq. Mi.	Head, Feet.	Approximate Turbine Cap.
Trenton Falls	375	265	333
Herkimer	583	30 to 33*	385

*At upper or paper mill level; 12 to 15 feet additional fall on lower level.

The principal provision of the contracts is to the effect that the Water Company may divert, without compensation, from any excess flow over the amount required by the plants in question. The Water Company may either divert such water directly or impound it in storage reservoirs for use in times when the natural flow does not exceed the requirements of the mills. This apparently simple arrangement is, so far as the writer is aware, the first of its kind. It has been in use two years and is found to be practicable to carry out in operation.

The conditions to be met were as follows: The Gas and Electric Company contemplated a progressive scheme of power development in which the construction of storage reservoirs as a private enterprise forms an element. The Water Company, on the other hand, desired that the amount of its diversion should be without restriction. It is believed that both of these requirements are satisfied. In the first place the Water Company cannot take any water which would otherwise be actually used by the power interests; hence, if the capacities of the power plants are increased, the limit above which the Water Company can divert without compensation will simply be raised. In the meantime, the Water Company is enabled to divert above a lower limit, and in so doing it works no injury to the existing power development, but is itself saved the outlay for enlarged compensation reservoirs until actually required. It might at first appear that the power interests, by sufficiently extensive installation and storage, could practically prevent the Water Company from taking any water. As a matter of fact, the Water Company is definitely assured of an abundant supply for any reasonable future demand. This assurance rests upon the facts, first, that it is impracticable to completely regulate this stream by storage, and second, the Water Company controls storage sites sufficient for its own requirements with any reasonable basis of power development.

West Canada Creek is an excellent water yielder, situated on the southwest slope of the Adirondacks, where the moisture-laden winds from Lake Ontario precipitate the maximum amount of rain and snow. Gaging records for dry years indicate that with the present basis of power development it will never be necessary to compensate during more than one hundred to one hundred and

twenty days without opportunity to replenish the storage, and even so long a period of deficiency will probably occur on an average only a few times in a century.

It follows that by providing a storage capacity equivalent to say one hundred days' supply the Water Company is enabled to make perpetual diversion. The present diversion is 6 000 000 gallons per day, and will be increased to 10 000 000 gallons per day in the near future. Of course, no effort is made to secure identity of the diverted and compensatory waters. The compensation reservoirs may be located at any point in the drainage basin, but if remote from the water supply intake, a reasonable time allowance is to be made between letting down the compensation and making the diversion. The real purport of these contracts is that whenever the flow in the stream at either of the mills is less than the amount required for power, the Water Company, if it is diverting water at its intake, likewise turns into the stream an equal amount of stored water, so that there is no change or diminution at any time in the flow utilized by the mills. The contracts are thus entirely flexible as to the amount of power that may be developed, or the amount of diversion that may be made so long as the capacity of the stream is not exceeded. The Water Company is under bond for the fulfillment of its contract, and in case of its failure, the power interests have the same remedies at law as if no compensation had been attempted.

One feature of the system is the maintenance of accurate weirs and gages to determine both the inflow to and the outflow from the storage reservoirs, as well as the flow in the West Canada Creek above the Gas and Electric Company's plant, and again near the mouth of the stream, above the Herkimer mills.

Carrying out the provisions of these contracts costs the Water Company a moderate amount, but, on the other hand, the pecuniary value of the compensation may be judged from the fact that the diversion of 10 000 000 gallons per day under 265 feet head, as utilized at Trenton Falls, would represent the destruction of 325 net horse-power.

The contracts were drawn jointly by several attorneys of experience in matters of water rights, with the assistance of the writer.

CONCLUSIONS.

1. Compensation in kind should not be attempted on a stream where the natural low-water flow plus the feasible storage development will not supply more than the total requirement for water supply and power.

2. Arbitrary rates of compensation should be avoided. The basis of compensation should be made so flexible as to admit of the best utilization of all the water of the stream in the most economical manner.

3. Legislation should be secured by which the will of the majority of riparian owners can be enforced in the matter of storage development and stream regulation, and which will prevent a minority of the riparian owners from either blocking a storage or compensation project, or from receiving benefits therefrom for which they do not pay.

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DISCUSSION.

Mr. Charles W. Sherman * (*by letter*). Reference has so often been made to the attempts to furnish "compensation in kind" in connection with Boston's Cochituate Water Works, that an authoritative statement of just what steps were taken and of the results

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obtained may be of interest, especially as the information is not readily available to many. The following data from Bradlee's history of the Boston Water Works * are accordingly submitted:

"The purchase of White Hall Pond, in Hopkinton, was made November 4 [1846], by the Committee on Water, under the resolve passed April 21, . . . for the sum of $25 000, with the intention of using it as a Compensating Reservoir to flow into the Concord River as a substitute for Long Pond water, whenever that should be diverted from its natural channel to the injury of those who were entitled to the use of it." . . . "The actual cost of this Reservoir, after the dam was built and the improvements made, was $29,534.36." (Page 100.)

"At this time [December 13, 1847], the [Water] Commissioners thought it best to build Compensating Reservoirs, to serve as a substitute for the waters which might be diverted from Concord River, and at their request the following order was passed [by the City Council]:

"*Ordered;* that the Water Commissioners be authorized to make such purchases of lands and water rights in the name and on account of the city of Boston, and to erect such dams, embankments, and other works, as they shall deem necessary and expedient for forming Reservoirs of water to serve as a substitute for the waters which may be diverted from Concord River, and to make payment therefor, in the same manner as for lands and water rights purchased by virtue of the act for supplying the city of Boston with pure water; *provided,* the same does not exceed the sum of fifty thousand dollars." (Page 71.)

"January 13, 1848, the Commissioners purchased of Mr. Amory Maynard, the Marlborough and Boon Pond Reservoir, for the sum of $21 148.90; they finally cost, however, when the dam was completed and the reservoir ready for use, $43 170.59." (Page 109.)

In 1854, the Whipple suit for damages for diverting the waters of Lake Cochituate from Concord River was brought, and resulted in the settlement of all claims for $6 678.90. (Page 170.) This seems to have demonstrated the futility of the attempt to furnish "compensation in kind."

"The Marlborough Reservoir was sold this year, July 29 [1858], to Mr. Amory Maynard, for the sum of $8 000." (Page 184.)

* N. J. Bradlee: "History of the Introduction of Pure Water into the City of Boston, with a Description of Its Cochituate Water Works." Boston, 1868.

In 1859, "the proprietors of Sudbury meadows . . . memorialized the city of Boston for payment for damage done their property by letting down water from the reservoir at unseasonable times." . . . The water board finally proposed that —

"The city of Boston will convey to some responsible agent or committee, authorized to act in behalf of the proprietors, by quitclaim deed, all the right, title and interest which the city possesses in and to the reservoir [Whitehall Pond], at Hopkinton, with its dam, gate-house, and flume, to have and to hold, and lawfully manage and control the same as they please." (Page 193.) This was done.

Mr. Louis L. Tribus.* If I had known, Mr. President, that the Newton case was to be brought up here, I would have been very glad to have shown a map exhibiting some features, which were rather interesting in some respects. It is one of the few cases in this country where a reservoir has been actually constructed partially — not wholly, as the paper under discussion would seem to indicate — for the purpose of compensating in kind. The town of Newton, N. J., was not a riparian owner on the stream in question, so could only act through "agreements" rather than by "rights." On this stream there were three mills, neither one having storage capacity to supply other than a daily regulation of the mill use. The upper owner, about forty years or so before the Newton work was carried on, diverted a small stream from its natural course into an artificial pond made at the outlet of a natural lake, the combined flows later reaching the same original brook. Many years ago the level of the lake was raised slightly by a small earth dam, but this, following construction of the lower pond, was allowed to practically disappear so that the waters of the pond and lake were reasonably free to flow back and forth. This upper owner used at will the natural flow of the stream and the outflow from lake and pond, without regard to the interests of the lower owners who had no interest, through ownership, of any pondage along the upper stream.

Newton bought some of the rights of this upper owner and the fee in the original lake. It fully diverted the upper stream, the one that this original owner had partially diverted into the upper lake, and erected a substantial masonry dam, raising the high

* Consulting Engineer, New York City.

water level some five feet. In that upper five feet there was stored at least twice as much water as would suffice the uses of the town of Newton for a whole year, and that upper five feet could easily be stored in two days' flow of an ordinary winter or spring storm from the direct and diverted watershed. In fact, it has been filled in about twenty-four hours.

The speaker, as engineer for the town, urged the commissioners to enter into written agreements with the lower mill owners. They thought, however, that in view of the expenditure that Newton was incurring for raising the level of the upper lake and the general friendly feeling for the enterprise, there would be no need of an agreement, as there were no actual physical damages, but, instead, betterments. The agreement with the upper owner was such that he was to control the gate of the lower pond at will, and the town was to feed the lower pond from its stored waters as he should require, keeping the water level in the lower pond practically at a standard.

The lower owners made no objection, the works were built, and things went on for nearly two years, the mills all receiving a distinct benefit; but then suits were brought, and the court decided, on the old principle of law, that damages must be recognized in money and that theoretically (it could not say practically, because there was no practical damage) these owners were deprived of the amount of water that Newton could take through its mains out of the watershed into another watershed; therefore, it was the flow of a 10-inch pipe (the main line) for twenty-four hours for 365 days in the year which must be made the basis of an award for damages. The upper owner from whom much of the property had been purchased had grace enough not to bring any suit at that time. He, however, did bring a suit later which, after a lengthy trial, was settled out of court for a small sum. He ought never to have won in view of the special considerations in his case, but the court would probably have awarded damages on the technical questions involved rather than actual damages incurred.

Mr. Allen Hazen.* I am under the quite distinct impression that the city of Fitchburg, Mass., has compensated mill owners

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in kind, and built a reservoir and turned it over to the mill owners, to be operated in lieu of water diverted from other tributaries of the stream for uses of the city; but it is my impression that that arrangement was carried out by agreement and could not have been carried out in any other way. I do not want that to be taken on my statement, but some one should make a definite statement of it and it should go in the record, I think, in connection with these other cases.

Mr. Thomas H. McKenzie.* I happen to be familiar with one instance in which compensation in kind has been made, at Meriden, Conn.; that was partly by agreement and partly by legislation. All of the mill owners agreed to a certain size and capacity of reservoir in lieu of money damages, and the city of Meriden secured legislation authorizing the construction of the compensating reservoir and the issuing of bonds to cover the cost, and I believe the arrangement has worked very satisfactorily. That is the only case which has ever come to my knowledge.

Mr. Hazen. I think, Mr. President, if the principle could be established there would be many cases where developments would be possible that are not considered possible under present laws, and that great good might come from it both to some of our cities and also to manufacturing corporations upon rivers.

Mr. Leonard Metcalf.† Mr. President, just to get the matter on the record, it may be well to mention that I think something of the sort was done by the mill owners on the Blackstone River, — I should have said the Draper Company took the initiative in the matter, — and they built a dam at North Pond for storage purposes solely. I think that Arthur T. Safford, of Lowell, will probably know the facts in regard to the matter, so it can be looked up in connection with this paper.

Mr. David A. Hartwell ‡ (*by letter*). In 1891 the city of Fitchburg was greatly in need of an additional water supply, and two natural ponds in the town of Westminster seemed the most desirable of any possible source. These were Meetinghouse Ponds with a water surface of 152 acres and a watershed of 942 acre (including the pond), and Wachusett Lake, partly in Westminster

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‡ City Engineer, Fitchburg, Mass.

and partly in Princeton, with a water surface of 134 acres and a watershed of 976 acres (including the lake). Franklin Wyman owned and operated a paper mill at what was called "The Narrows," and controlled the waters of Meetinghouse Pond and Wachusett Lake. He also had a storage reservoir called Wyman reservoir above his mill, with a watershed of 3 032 acres in addition to the water sheds of Meetinghouse Pond and Wachusett Lake, the overflow from which enters said Wyman reservoir. The dam of the Wyman reservoir was in such poor condition in 1891 and for some years previous thereto that the county commissioners would not allow him to fill it.

The city of Fitchburg purchased of Mr. Wyman, for $75 000, all his storage and flowage rights, his paper mill and adjacent houses and other buildings and a considerable area of land. Section 4, Chapter 60, of the Acts of 1892 of the Massachusetts Legislature relative to an additional water supply for the city of Fitchburg reads as follows:

"Said city is also authorized to take and hold, by purchase or otherwise, the water of Wyman reservoir, so-called, in the town of Westminster, and the waters which flow into and from the same, and any water rights connected therewith, to be used as a compensating reservoir for all damages that would otherwise arise to mill owners by reason of the taking and diverting of the waters of Meetinghouse Pond and Wachusett Lake; and to take and hold in like manner such lands as may be necessary for building, erecting, and maintaining a dam for storing and distributing said waters. Said city is authorized to contract with mill owners whose rights are affected, in relation to the manner and mode of using, controlling, and operating said compensating reservoir."

Acting under this section the city built a new dam for the Wyman reservoir so as to store up to the limit of the flowage rights, which raised the level of Wachusett Lake about four feet. The cost of this dam, including the gate house and contingent work, was about $50 000. This compensating reservoir, not including Wachusett Lake, has an area of 203 acres and an available storage of 419 000 000 gallons.

An agreement was made with all the mill owners on the north branch of the Nashua River and the mill owners on the main river between the junction of the north and south branches at Lancaster

and its confluence with the Merrimac at Nashua. By this agreement the mill owners released all rights to the waters of Meetinghouse Pond and Wachusett Lake and the city built the Wyman dam. That part of the agreement relating to said Wyman reservoir reads as follows:

"Now, therefore, the said city hereby covenants and agrees with the said parties of the second part, and with each of them, their heirs, executors, administrators, successors, and assigns, that it will forever maintain said reservoir at its present capacity for the sole use and benefit of said parties of the second part, their heirs, executors, administrators, successors, and assigns, and that it will take whatever measures are necessary to prevent any interference with, or diversion of, the waters which flow into the same and the sources of supply by which the same is filled, and that it will forever keep the walls and gates of said reservoir in good repair so that the water thereof, and no part thereof, shall be allowed to escape except as hereinafter provided, and that it will forever keep and maintain in good repair the dam now located at the eastern end of said reservoir at its present height and that it will construct and forever maintain at the eastern end of said reservoir a proper gate or gates to control the waters of the same, and that it will always supply and employ a suitable man, or men, at its own expense, to care for said gate, or gates, at said dam, and to so adjust the same that there shall be as nearly as possible an uniform flow of water, each and every day, except Sundays and legal holidays, throughout each and every year hereafter, into the natural channel as it exists to-day, and to so adjust the said gate or gates that said flow of water shall be as great as possible consistently with the uniform flow thereof; that it will permit none of the waters of said reservoir to be used for any other purpose than is herein provided, and that the said waters of said reservoir shall at all times when said gates are open flow unused and without interruption of any kind into the said channel, and shall be used for no other purposes except as a part of the waters of the Nashua River after they shall have gone into the said stream, except, however, and it is hereby expressly provided, that it shall be lawful for the city in case a serious conflagration occurs in West Fitchburg, or in the city of Fitchburg proper, or in case the pipes which carry the waters of Wachusett Lake and Meetinghouse Pond into the city of Fitchburg shall break above the said Wyman's reservoir, to draw the waters of the said reservoir into the pipes which form the city's system of water supply, during the existence of said conflagration, or until the said break shall have been repaired by due diligence on the part of the city."

Thus the city of Fitchburg, with an expense of about $125,000, purchased water rights and settled all claims for loss of power by which, under proper development, was made available an additional supply of about 4 000 000 gallons a day.

Mr. T. H. McKenzie (*by letter*). I happen to know of one instance in which compensation in kind was made by the city of Meriden, Conn., to the mill owners on Sebethe River in the town of Berlin, in the year 1868.

The city of Meriden diverted the water from one square mile of watershed which was tributary to six mills which were in operation and one mill privilege not in operation. The fall at the privileges in operation was about as follows: 18, 14, 36, 12, 8, and 8 feet; total, 96 feet fall. The compensating reservoir cost $18,000, which is equivalent to $187.50 for each foot fall for one square mile of watershed.

This settlement was by agreement with the mill owners to accept a certain size and capacity of reservoir in lieu of money damages, and afterwards by the city of Meriden securing legislation authorizing the taking of land and the issuing of bonds to cover the cost of construction. The reservoir is of 52 000 000 gallons capacity. The arrangement worked satisfactorily for many years.

At the time the reservoir was built, three of the falls, 18, 36, and 12 feet, respectively, were owned by one company; this same company owned property below the compensating reservoir, and above all of the mills another storage reservoir of double the capacity of the compensating reservoir. The water from the compensating reservoir had to pass through this large reservoir before reaching the factories. The company owning the three falls of 18, 36, and 12 feet, by common consent of all of the mill owners, controlled the gates at the compensating reservoir as well as the other large storage reservoir. In course of time the large company sold the mill with the 12-foot fall, but did not sell their rights in the large storage reservoir. Then trouble began to brew. The owner of the large powers who controlled the gates drew all of the water from the compensating reservoir and still held the water in their storage reservoir. The large company found it necessary to shut down their factories for a month in July, when the party below with 12-foot fall wanted to run; very little water was running in the

stream, not enough to run a mill, so a suit was brought against the large company to compel it to let water down. The large company claimed that the water was all drawn from the compensating reservoir and that the water in the large storage reservoir below all belonged to them as it was stored water from the spring floods. The large company won in the suit, and held the water.

Aside from this one incident, the plan of compensating in kind might be called a success in this case, although if one of the proprietors of the mills wished to put his property to other use than for power purposes, the stored water would be of little use to him, while the money would be useful and would be drawing interest.

As to the saving in the Meriden case, it is somewhat doubtful about any saving in cost. The cost of the reservoir in the Meriden case was about $187 per foot fall for one square mile.

The cost in a large number of cases in which I have been engaged and where money damages were paid ranged from $100 to $210 per foot fall per square mile of watershed diverted. This price refers to mill powers which are actually developed and in operation. In the Meriden case, the cost of the compensating reservoir figures about $200 per foot fall per square mile of watershed diverted.

Where a large number of mills are to be settled with on a stream it would be much cheaper to settle by storage of water.

Where only a few mills are to be settled with and a small area of watershed is diverted, it would be cheaper to settle by paying money for damages.

I doubt, however, about any general law being enacted that will compel the claimants to accept something in lieu of money for damages.

The matter of drawing off the water and controlling the gates of a storage reservoir which is owned in partnership is a difficult problem to handle. One party may want to run his mill and another want to shut down his mill and save the water.

I had occasion a few years since to make surveys and plans for a large storage reservoir on the east branch of the Farmington River in the town of Otis, Mass., for the Farmington River Power Company. There were originally seven equal owners in the company, which was organized for the purpose of building the first storage reservoir on this stream. After the reservoir was built two of the

owners, in order to control the gates at the storage reservoir, bought out the other five owners. When it came to the matter of deciding on the building of the new storage reservoir the seven mill owners were all called upon to take each one seventh of the stock. The five who had sold out declined to take, saying to the other two, "You are the Farmington River Power Company; you control the stock of the company and the stream"; so, of course, the second reservoir was not built. I mention this instance to show the difficulties of handling such partnership matters in the control of reservoirs.

Mr. Horton (*by letter*). Since this paper was prepared, I have been informed that an additional case of compensation in kind exists in New Jersey. Unfortunately, the details are not available further than that a system of compensation was established many years ago in connection with the taking of water from a lake or stream for the supply of navigable canals.

PROCEEDINGS.

June Outing.

Plymouth, Mass., June 24, 1908.

The June meeting of the New England Water Works Association was held at Plymouth, Mass., on Wednesday, June 24, 1908, with the following attendance:

Members.

S. A. Agnew, R. W. Bagnell, Lewis M. Bancroft, Joseph E. Beals, Arthur E. Blackmer, James W. Blackmer, James Burnie, Charles E. Childs, John W. Churchill, Frank L. Clapp, R. C. P. Coggeshall, Michael F. Collins, George E. Crowell, John C. De Mello, Jr., Edward D. Eldredge, Charles R. Felton, John N. Ferguson, Arthur N. French, Albert S. Glover, Frank H. Gunther, Frank E. Hall, Horace G. Holden, Willard Kent, George A. King, A. R. McCallum, Hugh McLean, A. E. Martin, John Mayo, Leonard Metcalf, Frank L. Northrop, J. K. Nye, Oren E. Parks, William H. Pitman, Leonard C. Robinson, Henry W. Sanderson, A. L. Sawyer, Walter H. Sears, Edward M. Shedd, Charles W. Sherman, William E. Smith, Harry L. Thomas, Robert J. Thomas, William H. Thomas, James L. Tighe, D. N. Tower, Charles K. Walker, Lettice R. Washburn, Robert S. Weston, John C. Whitney, L. J. Wilber, George E. Winslow. — 51.

Associates.

Anderson Coupling Company, by Charles E. Pratt; Builders Iron Foundry, by A. B. Coulters and F. N. Connet; Chapman Valve Manufacturing Company, by Edward F. Hughes; Hersey Manufacturing Company, by Albert S. Glover; International Steam Pump Company, by Samuel Harrison; Lead Lined Iron Pipe Company, by T. E. Dwyer; Ludlow Valve Manufacturing Company, by A. R. Taylor; H. Mueller Manufacturing Company, by George A. Caldwell; National Meter Company, by J. G. Lufkin; Neptune Meter Company, by H. H. Kinsey; Pittsburg Meter Company, by F. L. Northrop; Rensselaer Manufacturing Company, by C. L. Brown; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by Edw. M. Shedd; Union Water Meter Company, by F. L. Northrop. — 15.

Guests.

M. M. Garvey, Lawrence, Mass.; Miss Henrietta C. Walker, Manchester, N. H.; Mrs. A. S. Glover, Newton, Mass.; Mrs. F. H. Gunther, Dracut, Mass.; S. M. Spencer, Malden, Mass.; Mrs. Geo. E. Winslow, Waltham, Mass.;

THE SURVIVING CHARTER MEMBERS OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

(From a photograph taken at Plymouth, Mass., June 24, 1908.)

H. G. HOLDEN. R. W. BAGNELL. C. K. WALKER.

F. E. HALL. A. S. GLOVER. R. C. P. COGGESHALL.

I. M. Low, superintendent, Weymouth, Mass.; Mrs. J. N. Ferguson, Boston, Mass.; Miss Nellie Collins, Lawrence, Mass.; Mrs. L. J. Wilber, Brockton, Mass.; Mrs. F. N. Connet, Providence, R. I.; Mrs. A. E. Blackmer, Plymouth, Mass.; Mrs. Walter H. Sears, New York, N. Y. — 13.

[Names counted twice — 3.]

A business meeting was held at the Armory, where the Association was welcomed by representatives of the town, and the following were admitted to membership:

Dana M. Wood, assistant engineer, United States Geological Survey, Boston, Mass.; Frank A. Marston, civil engineer, with Metcalf & Eddy, Boston, Mass.; H. Lester Newhall, third assistant, city engineering department, Brockton, Mass.; Ira C. Forbes, mechanical engineer, West Shokan, N. Y.; Thomas Gray, manager High Falls Power Company, Ellenville, N. Y.; James F. Sanborn, assistant engineer, New York Board of Water Supply, 236 Main Street, Poughkeepsie, N. Y.; Nicholas S. Hill, Jr., consulting engineer, 100 William Street, New York City; Charles L. B. Anderson, consulting municipal engineer, Atlanta, Ga.; C. Sherman Rex, Jr., superintendent Creston Water Works Company, Creston, Ia.; Francis C. Hersey, Jr., water commissioner, Wellesley, Mass.; and Henry A. Young, chief engineer Camaguey Water Works, Camaguey, Cuba.

Most of the members then proceeded to the shop of the Plymouth Water Works on Howland Street, where the construction of the Phipps cement-lined and jacketed pipe, which is exclusively used in Plymouth, was witnessed, and the process was fully explained by Supt. A. E. Blackmer.

Pilgrim Hall and other places of interest were visited by a number of the party. Special electric cars were then taken to Hotel Pilgrim, where luncheon was served and where a photograph was taken of the surviving charter members of the Association, Messrs. H. G. Holden, R. A. Bagnell, Charles K. Walker, Frank E. Hall, A. S. Glover, and R. C. P. Coggeshall. [This photograph is reproduced herewith.] Many of the party then visited the water works pumping station and inspected the work of laying the cement-lined pipe, which was in progress near by.

Twenty-Seventh Annual Convention, Atlantic City, N. J., September 23, 24, and 25, 1908.

The Twenty-Seventh Annual Convention of the New England Water Works Association was held at Atlantic City, N. J., on September 23, 24, and 25, 1908. The headquarters of the Association were at the Traymore Hotel, and the meetings were held in the Assembly Hall at the hotel.

The following members and guests were in attendance:

Members.

S. A. Agnew, Kenneth Allen, M. N. Baker, C. H. Baldwin, A. F. Ballou, F. A. Barbour, G. W. Batchelder, E. W. Bemis, C. R. Bettes, F. E. Bisbee, James Burnie, T. J. Carmody, C. E. Chandler, J. H. Child, C. E. Childs, W. F. Codd, W. R. Conard, G. K. Crandall, John Doyle, M. J. Doyle, E. D. Eldredge, G. H. Felix, B. R. Felton, J. H. Flynn, Murray Forbes, F. L. Fuller, W. B. Fuller, A. S. Glover, Wallace Greenalch, C. A. Hague, F. E. Hall, W. C. Hawley, Allen Hazen, G. T. Ingersoll, G. G. Kennedy, E. W. Kent, Willard Kent, G. A. King, J. J. Kirkpatrick, Morris Knowles, B. C. Little, E. E. Lochridge, F. H. Luce, F. A. McInnes, T. H. McKenzie, Hugh McLean, P. A. Maignen, A. E. Martin, G. F. Merrill, Leonard Metcalf, F. L. Northrop, H. N. Parker, E. M. Peck, E. L. Peene, T. A. Peirce, E. A. Pickup, A. A. Reimer, P. R. Sanders, W. J. Sando, A. L. Sawyer, E. M. Shedd, P. S. Smith, J. F. Sprenkel, L. A. Taylor, R. J. Thomas, J. L. Tighe, D. N. Tower, J. C. Trautwine, Jr., L. L. Tribus, J. H. Walsh, C. S. Warde, J. S. Warde, R. S. Weston, I. S. Wood, C. L. Wooding, Timothy Woodruff. — 76.

Honorary Member.

F. W. Shepperd. — 1.

Associates.

Allis-Chalmers Company, by W. J. Sando; Anderson Coupling Company, by Charles E. Pratt; Builders Iron Foundry, by A. B. Coulters and E. C. Atkins; Central Foundry Company, by J. H. Morrison; Chapman Valve Manufacturing Company, by Edward F. Hughes; The Fairbanks Company, by C. H. White, West DeHaven, and J. F. O'Brien; Hays Manufacturing Company, by T. J. Nagle and C. A. Eaton; Hersey Manufacturing Company, by Albert S. Glover, H. D. Winton, W. C. Sherwood, and W. T. Kershaw; International Steam Pump Company, by Samuel Harrison; Lead Lined Iron Pipe Company, by Thomas E. Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould; Charles Millar & Son Company, by Charles F. Glavin; H. Mueller Manufacturing Company, by George A. Caldwell, F. B. Mueller, O. B. Mueller, and F. W.

Cruckshank; National Meter Company, by C. H. Baldwin, John C. Kelley, W. P. Oliver, J. G. Lufkin, and Lewis H. Nash; National Water Main Cleaning Company, by D. H. Buell; Neptune Meter Company, by H. H. Kinsey, F. A. Smith, and C. A. Vaughan; Norwood Engineering Company, by H. W. Hosford; The Pitometer Company, by L. B. Shoemacher; Pittsburg Meter Company, by F. L. Northrop, T. C. Clifford, A. G. Holmes, and V. E. Arnold; Rensselaer Manufacturing Company, by F. S. Bates and C. L. Brown; Ross Valve Manufacturing Company, by Wm. Ross and Adam Ross, 2d; A. P. Smith Manufacturing Company, by F. N. Whitcomb and John W. Strachbeim; Thomson Meter Company, by E. M. Shedd, S. D. Higley, W. S. Cetti, and J. L. Atwell; Union Water Meter Company, by F. E. Hall; United States Cast Iron Pipe & Foundry Company, by F. W. Nevins and W. B. Franklin; Water Works Equipment Company, by Walter H. Van Winkle and W. H. Van Winkle, Jr.; R. D. Wood & Company, by Wm. P. Brew and Edward J. Lane. — 55.

GUESTS.

Joseph F. Biladeau, Pittsfield, Mass.; Mrs. Louis L. Tribus, Master Lucian Hall Tribus, Mrs. A. A. Knudson, Mrs. Fred A. Smith, Miss Bessie J. Warde, Mrs. Charles H. White, Mrs. Kenneth Allen, Miss Mildred Arnold, Mrs. F. W. Shepperd, Mrs. J. F. O'Brien, Miss Zada O'Brien, F. W. Stodder, Mr. Thomas Liston, Mr. I. S. Holbrook, Miss Leda Mueller, Mrs. F. W. Cruckshank, Mrs. H. Mueller, Mrs. Edmunds, Mrs. John C. Kelley, Miss Kelley, New York City; Mrs. A. E. Martin, Mrs. Clara A. Kilburn, Mrs. E. E. Lochridge, Springfield, Mass.; Mr. and Mrs. L. Van Gilder, Mr. Wm. H. Randolph, Miss T. Strauss, Mr. Stanley Johnson, Mrs. M. Somers, Miss S. Tilton, Miss Elsie Reuscher, Mrs. H. H. Decker, B. F. Souder, Miss C. May Chase, Atlantic City, N. J.; Mrs. T. A. Peirce, Mrs. Joseph W. Vaughan, East Greenwich, R. I.; Mrs. Francis H. Luce, Woodhaven, N. Y.; Mr. Albert Blauvelt, Chicago, Ill.; Mrs. A. A. Reimer, East Orange, N. J.; Mrs. E. C. Atkins, Mrs. I. S. Wood, Providence, R. I.; Mrs. John Doyle, Worcester, Mass.; Miss A. E. Nugent, Mrs. Albert S. Glover, Mrs. H. F. Gould, Mrs. John H. Flynn, Boston, Mass.; Mr. and Mrs. James P. Bacon, Cambridge, Mass.; Mr. M. J. Gray, Burlington, N. J.; Mr. James G. Hill, Mr. Patrick Kelley, Mrs. R. J. Thomas, Miss Katherine Walsh, Miss Charlotte Walsh, Lowell, Mass.; Hon. Horace S. Van Worst, Charles B. Pond, Schenectady, N. Y.; Mrs. John C. Trautwine, Jr., Mr. Joseph Thompson, Mr. George Costello, Mr. W. F. McCarthy, Philadelphia, Penn.; Mrs. Edward L. Peene, Yonkers, N. Y.; Mrs. T. C. Clifford, Miss Lois I. Clifford, Pittsburg, Penn.; Mrs. Murray Forbes, Greensburg, Penn.; Mrs. George H. Felix, Reading, Penn.; Mrs. George G. Kennedy, Harrisburg, Penn.; Mr. W. F. Penn and Miss Katherine Penn, Morganza, Penn.; Mr. Edmund T. Scott, Trenton, N. J.; Miss May I. Agnew, Mr. John J. Heavey, J. W. Griffin, Thomas Rooney, Hon. H. O. Wittpenn, Alex S. Hanult, and Edward W. Henry, Jersey City, N. J.; Mr. Frank S. Fithean, Camden, N. J.; Mrs. Small, Auburn, Me.; Miss Helen C. Doorty, Buffalo, N. Y.; Miss Mary A. Sargent, Cleveland, O.; Mr. R. W. Pratt, Columbus, O.; Miss Grace Merritt, San Fran-

cisco, Cal.; Mr. T. A. Collins, Lawrence, Mass.; Mrs. T. J. Carmody and Mrs. J. J. Kirkpatrick, Holyoke, Mass.; Mrs. Wm. F. Codd, Nantucket, Mass.; Mrs. D. N. Tower, Cohasset, Mass.; Mrs. F. A. McInnes and Miss Frances McInnes, Boston, Mass.; Mrs. Willard Kent, Narragansett Pier, R. I.; Mr. R. S. Kellogg, Mr. Alvan Donnan, Washington, D. C.; Mr. Frank Little, Mrs. David Little, Rochester, N. Y.; Mrs. O. B. Mueller, New Rochelle, N. Y.; Mr. John K. Guinn, Utica, N. Y.; Mrs. Charles R. Bettes, Far Rockaway, N. Y.; Mr. F. J. Deutschbeim, Albany, N. Y.; Mr. H. R. Beebe, Utica, N. Y.; Mr. T. D. Faulks, Newark, N. J.; Mr. and Mrs. Jas. Donovan, Middletown, Conn.; Mrs. Charles E. Chandler, Norwich, Conn.; Mr. Albert S. Sessions, Bristol, Conn.; Mr. Robert W. Grant, Woonsocket, R. I.; Mr. Peter J. Ford, Dr. A. Robin, Mr. John Keule, Wilmington, Del.; Mr. F. E. Puffer, New York City; Mr. and Mrs. James J. Griffin, Middletown, Conn.; Mr. Arthur W. Burnie, Biddeford, Me. — 113.

[Names counted twice — 6.]

Morning Session, Wednesday, September 23.

President A. E. Martin called the convention to order and spoke as follows:

Gentlemen of the New England Water Works Association and Guests, — It is hardly necessary for me to reiterate my statement of last January that I am proud to stand before you to-day as president of this Association, which includes among its members men of marked and proven ability in the profession of water-works construction and maintenance, men who are willing to give deep study and much time to the different subjects in which we are interested, and then bring before us, in well-written papers, ideas which benefit us all.

Many of those who organized this society have joined the silent majority, and their faces are much missed at our conventions, but the same spirit is manifest to-day that was shown twenty-seven years ago, when that little body of men first associated themselves together for mutual help and improvement.

I am pleased to greet you in Atlantic City to-day. For a long time many of our members have desired to hold a convention in this city, and to-day we see the fruition of those wishes.

To me it is somewhat of a red-letter day in another way, for besides being the opening day of this convention of our Association, it also marks the beginning of another lap on my life's journey. Something more than *twenty-seven* years ago, on the

twenty-third of September, in an old red brick farmhouse in the good old town of Brooklyn, Conn. (that land of steady habits and wooden nutmegs), at very early hour in the morning (so I am credibly informed), the interesting event occurred which made it possible for me to stand here to-day as your presiding officer.

I feel that I must digress here to say that my enforced early rising on that eventful morning undoubtedly prejudiced me against the practice ever after, for it has been only with a most unwilling spirit that I have ever indulged in such a luxury since.

But laying all jesting aside, it will always be one of the pleasantest incidents of my life that on this anniversary I had the pleasure and honor of presiding at the twenty-seventh annual convention of the New England Water Works Association.

I will not take up more of your time, for I know you are all anxious to hear another who is present and who, doubtless, considers it a pleasure as well as a privilege to greet you.

I take great pleasure in introducing his honor, Mayor Stowe, who will give you a welcome to this fair city by the sea.

Mayor Stowe. *Mr. President and Members of the Association,* — I assure you that it gives me great pleasure to come before you this morning, and I wish particularly to congratulate the President on his birthday. It must be very pleasant for him, especially if he has his family with him, and I hope that at least once in twenty-seven years they can all have a day of recreation at the seaside. I understand this is the first time that your Association has ever met in our city. I am surprised that a matter so important to you and to us has been left so long unattended to. [Laughter.] You gentlemen are engaged in an occupation for the benefit of humanity, and you should be looked up to with more appreciation, perhaps, than any of the rest of us who are engaged in municipal affairs, for it is your particular duty to see to it that we have good water. It has been my privilege during the past few years to appoint the water commissioners of our city, and I can say that for eight or nine years we have had a very efficient board. As you know, here on the seashore we cannot get our water from driven wells, and there is no fresh water stream, and we are compelled to go to the main land for our supply. I can assure you that you can drink our water here with the certainty that you are drinking

something that cannot be equaled in the shape of water within a radius of at least two or three hundred miles.

We are proud to have you with us, and we hope to receive much benefit from your visit. We bid you welcome and extend to you the freedom of the city. I trust that you will feel at liberty to make all the investigation and inquiry into our affairs — to "butt in," if you please — that you desire; and we will be ready to listen and learn anything you can tell us which will better our condition, for certainly this body must possess a great deal of valuable information on the subject of water supply.

Now, Mr. President, as you know, our city is going through a rather strenuous ordeal in certain directions [laughter], and as I was not able to get to bed at all last night, I trust you will excuse me from making any further remarks. I will, therefore, close by repeating that I want you to feel free to do just as you please here, to feel that you belong to us as long as you stay here, and if I can be of any service to you at all I shall be only too happy. I thank you for this opportunity to speak to you. [Applause.]

THE PRESIDENT. I can assure you, Mr. Mayor, that the Association appreciates your welcome and will be glad to accept your courtesies.

On motion of Mr. George A. King, it was voted that the President be authorized to appoint a committee of five to nominate officers for the ensuing year. The following-named gentlemen were appointed as the committee: J. C. Whitney, Newton, Mass.; Leonard Metcalf, Boston, Mass.; George A. Stacy, Marlborough, Mass.; E. W. Kent, Woonsocket, R. I.; William F. Sullivan, Nashua, N. H.

Mr. John C. Trautwine, Jr., civil engineer, Philadelphia, Penn., read a paper on "Water Purification at Philadelphia," illustrated by lantern slides.

Adjourned.

AFTERNOON SESSION, WEDNESDAY, SEPTEMBER 23.

President Martin in the chair.

The afternoon session was devoted to a consideration of the subject of the conservation of the natural resources of the

country. The first item of the program was the report of the committee on this subject, and the president called upon Mr. M. N. Baker, who said:

"This committee was appointed a few months ago to take up the important question of the conservation of the natural resources of the country. It has seemed best to bring the subject before the convention in the form of papers by experts on those phases of it most important to our members. It was the intention to have papers on forestry, on water supply, and on coal. Unfortunately we were unable to secure a paper on coal; those on water supply and forestry will now be presented."

The first paper, entitled, "The Conservation of Water Resources," by Marshall O. Leighton, chief hydrographer, United States Geological Survey, Washington, D. C., was read by Mr. Horatio N. Parker."

An address on "Forestry," by R. S. Kellogg, of the United States Forest Service, Washington, D. C., followed, and the subject was discussed by Messrs: P. A. Maignen, Robert S. Weston, Allen Hazen, Frank L. Fuller, W. C. Hawley, Albert Blauvelt, M. N. Baker, H. N. Parker, Edward W. Bemis, George A. King, and A. A. Reimer. At the conclusion of the discussion President Martin said:

"Are we to understand that the committee is to be continued, and that we may have the pleasure of hearing something more from it in the future? This is a very important question and should be kept alive before the Association."

Mr. Baker. As I remember it, the appointment of the committee was at the suggestion of the Executive Committee of the Association because the subject was at the front, and the four leading national engineering societies had already appointed committees on the conservation of the natural resources of the country. What the pleasure of the Association may be as to continuing our committee I, of course, do not know.

The President. Unless there is objection on the part of any of the members, this report will be received as a report of progress and the committee continued for further work. There being no objection to that it will be so understood.

Adjourned.

Morning Session, Thursday, September 24.

President Martin in the chair.

The Committee on Standard Specifications for Fire Hydrants presented the following report of progress:

Boston, Mass., September 17, 1908.

To the New England Water Works Association, — The committee appointed to prepare specifications for street hydrants has had two meetings, an afternoon having been devoted to each, with the result that a general outline of specifications has been prepared, but we have not been able to get this into proper shape for presentation to the convention next week. We, therefore, can only report progress at the present time, with the expectation of submitting a little later to the Association a specification in reasonably complete form.

H. O. LaCount, *Chairman.*

The first paper on the program for the morning was a " History of the Haverhill Water Works," by Albert A. Sawyer, water registrar, Haverhill, Mass. Its reading was supplemented by some general observations by Mr. M. N. Baker on the importance of the preservation of historical data in connection with water works.

Mr. R. S. Weston, sanitary expert, Boston, Mass., read a paper on " Rubber Pipe Joints." The subject was discussed by Mr. Allen Hazen, Professor Bemis, Mr. W. C. Hawley, Mr. Van Gilder, and Mr. Charles E. Chandler.

Mr. Frank L. Fuller, civil engineer, Boston, Mass., submitted a paper entitled " Covered Reservoirs; Some Experience in the Use of Concrete in their Construction and in making them Watertight." Following the reading of the paper Mr. Fuller showed a large number of lantern slides illustrating his subject, and the exhibition of those closed the morning session.

Afternoon Session, Thursday, September 24.

President Martin in the chair.

The first paper of the afternoon was presented by Mr. Ermon M. Peck, distribution engineer, Hartford, Conn., his subject being " Meters and Water Consumption of the Hartford Water Works." Messrs. Allen Hazen, M. N. Baker, and H. N. Parker took part in the discussion.

A paper on "Meter Rates," by W. H. Richards, engineer and superintendent, New London, Conn., was read by Mr. George A. King. It was discussed by Prof. Bemis and Messrs. W. C. Hawley, A. A. Reimer, Hugh McLean, Albert Blauvelt, Leonard Metcalf, Frank L. Fuller, H. N. Parker, and J. H. Child.

Mr. Frank A. Barbour, civil engineer, Boston, Mass., presented a paper entitled, "The Water Service and Insurance Rates." Mr. Charles E. Chandler, Mr. Allen Hazen, and Mr. Leonard Metcalf took part in the discussion.

The regular program for the afternoon having been concluded, the President announced that Mr. Metcalf had in mind a matter which he desired to call to the attention of the convention.

Depth of Laying Water Pipes.

Mr. Leonard Metcalf. There is a matter which I should like to bring before the Association, which it has seemed to me might furnish an interesting subject for investigation. Some time ago it occurred to me that we had very little tangible or valuable information concerning the desirable depth at which water pipes should be laid in different latitudes and under different conditions, and I set out to prepare, and did prepare, a schedule of questions which I purposed sending to different water-works departments, in the hope of getting some light on this question, and getting some statistics in regard to actual experience with frozen pipes. Then it occurred to me that greater weight would be given to the investigation, and perhaps there might be a readier response to inquiries, if the work were undertaken by the Association, particularly in the light of the admirable work which some of our committees have done. So I thought of making a motion at this time, that a committee of seven, or whatever number might seem desirable to you, be appointed to gather statistics relating to the depth at which water pipes are laid, and the resulting experience with frozen pipes, not only in New England, but in different parts of the country if the scope of the inquiry could be successfully extended.

In going over this matter, I discussed the question with some friends, and wrote one or two letters which drew forth some very

pertinent suggestions, it seemed to me, and those I should be very glad to turn over to the committee should it seem desirable to you to appoint such a committee.

It seems to me it is not sufficient to inquire simply as to the depth at which pipes are laid in different works, and the character of the material in which they are laid, but that we should go further and inquire particularly into the cases that have arisen of frozen pipes, covering in our inquiry, aside from the elements which I have mentioned, that perhaps most important of all, the consumption of water through those very pipes. It is only from experiences of that sort, I believe, we can get the definite, tangible information that we need.

THE PRESIDENT. Do I understand you make that motion?

MR. METCALF. I make that motion, Mr. President.

MR. HAZEN. I second the motion, Mr. President. I have been greatly impressed at times, in walking over pipe lines and examining them, to observe that they were very much nearer the surface of the ground than common practice would seem to justify, and nevertheless they have not frozen; and I have wondered whether it was really safe to put pipes so near the surface as that, and, if so, if we were not wasting lots of money in putting them deeper.

MR. H. N. PARKER. It seems to me this would be a very valuable inquiry, but I think to the duty of that committee should be added that of collecting data in regard to the size of pipe and length of pipe that may safely be exposed in going over bridges, etc., without danger of freezing. That is a question I have often heard brought up, and it seems to me a very practical question for many superintendents, if they have a line of pipe crossing a ravine or a bridge, — whether it is necessary to cover it. I would have that included in the investigation.

MR. METCALF. In that connection, Mr. President, it might also be interesting, in order that it may be a matter of record here, to suggest that there has doubtless been experience with penstocks which will furnish very interesting data on that line. I know one came to my attention up in Maine which, I think, was 4 feet in diameter and absolutely exposed, and which lay idle for certain hours in the day, and in which they prevented freezing by partly

opening a small gate,— I think it was something like three or four inches, — and they had no trouble from freezing or anchor ice.

THE PRESIDENT. I would like to ask Mr. Metcalf if he has his motion in writing, or, if not, if he will put it in writing so that it can be acted on.

MR. METCALF. The gist of the motion is that a committee be appointed to gather statistics relating to the depth at which pipes are laid and the resulting experience with frozen pipes.

THE PRESIDENT. And would you like to add Mr. Parker's suggestion?

MR. METCALF. I would be very glad to incorporate that. I did not wish in any way to limit the scope of inquiry of the committee.

MR. W. C. HAWLEY. I would suggest in connection with the investigation that the temperature of the water that is passing through the pipe is quite an important factor, and I suppose of course that will be considered.

THE PRESIDENT. These items, perhaps, might be brought out in the questions which will be sent out by the committee.

MR. METCALF. If there is no objection, Mr. President, I will furnish the schedule of questions as I had arranged them myself, in order that they may be a permanent matter of record, not in any way to limit the action of the committee, but simply for the use of the committee, leaving the committee entirely free to modify, extend, or cut out any questions they may wish.

(The motion that a committee be appointed was adopted.)

MR. ALLEN HAZEN. I am going to suggest, Mr. President, as one member of the committee, a member of the Association who is not here, Mr. Kuichling. I happen to know he has made many calculations along this line, especially along the line of Mr. Parker's suggestion in regard to exposed pipe.

THE PRESIDENT. I will take the matter into consideration and announce the committee at the beginning of the evening session.

(The President subsequently appointed as the committee Messrs. Frank A. Barbour, Boston; R. S. Lea, Montreal, Canada; W. C. Hawley, Wilkinsburg, Penn.; R. Winthrop Platt, Columbus, Ohio; Emil Kuichling, New York City; W. C. Hoad, Lawrence, Kan., and Dabney H. Maury, Peoria, Ill.)

(The following correspondence and schedule of questions sug-

gested for the consideration of the committee were submitted by Mr. Metcalf.)

NOVEMBER 6, 1907.

MR. LEONARD METCALF, BOSTON, MASS.

Dear Mr. Metcalf, — I am much interested in your proposed collection of data regarding the depth of water pipes. I regard the inquiry as a most important one.

I see your schedule is arranged to take into account most of the points that I should be interested in, and I will only make some very general suggestions regarding it. I have not studied it as carefully as I would do if I had more time before leaving for the West, so what I say may duplicate what you already have.

In the first place, I would try to get the data relating to the particular mains which are frozen, and make this point very clear so that those who fill out your blanks will not give you the depths, materials, etc., that are generally used. It seems to me that the inquiry will be much more valuable to limit it strictly to those places where trouble has actually been experienced.

Limiting it in this way to those points, I should be especially interested to know the size of pipe; the depth; the character of the soil, especially whether clayey and impervious or gravelly and pervious; and the height of the ground water, if any, over the pipe. These matters I believe are all indicated on your schedule.

I should also want to know especially the length of pipe so exposed, if the location was specially exposed, and I should want to know as to the flow of water through the pipe, whether it was rapid or slow, continuous or intermittent. These are very hard matters to tabulate, but it would seem to me that they are likely to be of controlling importance in this matter.

I would also suggest that you make a special study to see if there has been any reduction in carrying capacity of pipes in exposed positions during continued severe winter weather. I have been especially interested in the last years in seeing a number of important leading-mains supplying cities running for miles with but little covering. Last week I walked over a mile of pipe that did not have over six inches of cover, much of the way the bells of the pipe being exposed, and here and there whole lengths of pipe. This pipe has been in use some years and there has been no reason to think that it has ever given trouble from freezing.

Now it would seem to me that in very cold weather anchor-ice would form on the top and sides of this pipe and reduce the carrying capacity. I believe that it is common experience for the penstocks and draft tubes of water-power plants, which are commonly exposed, to have their carrying capacity reduced in this way, and

it would seem to me that some of these leading-mains would show a corresponding reduction in carrying capacity. So long as there was no necessity for using the main to the limit of its capacity at these times, this reduction in carrying capacity very likely would not be noticed, but it does seem to me that it would be likely to occur and that its occurrence would be a matter of great importance, which would necessarily have to be taken into account in making adequate calculations. This is the more important because the maximum use of water often comes at times of continued severe cold weather.

Hoping that these rough suggestions will be of some use to you, and assuring you that I shall be very glad to see the compilation of your data when it is ready, I am,

Very truly yours,

ALLEN HAZEN.

The President presented Mr. Albert Blauvelt, associate manager of the Western Factory Association, Chicago, Ill., who desired the privilege of the floor to make a statement.

MR. ALBERT BLAUVELT. Mr. President, my statement will be very brief. The National Fire Protection Association have a standing committee on pipe, of which I am chairman, and I have come to this meeting in the hope of meeting those of your members who are most informed on the subject of cast-iron pipe. It transpires that some of them, at least, are not present at this meeting, and therefore such information as I shall need in the discharge of my duty will have to be obtained at some succeeding meeting.

The National Fire Protection Association is desirous of adopting a standard for pipe, and it appears that there are two or three printed specifications in the field. I simply rise to have it made a matter of record that I have discharged my duty in putting in a representation here, and I hope it will be the feeling among you individually that in the course of two years or three years or four years or five years, or whatever time is necessary, the discrepancies in pipe specifications can be eliminated and a uniform specification arrived at. One reason for my presence here is that the National Fire Protection Association is in touch with the International Association, and we had very much rather have uniform specifications in this country before taking up any question of standards with the Europeans.

[Inquiries suggested by Mr. Metcalf.]

WATER WORKS.—STATISTICS RELATING TO DEPTH OF LAYING PIPES.

Date of Reply________ Name________ Official Position________

________Water Works City or Town________ State________

(Municipal or Company Works. Give name if latter)

Distance of City from Ocean______miles
Mean Temperature, Deg. F.______°
Character of Supply________
(Gravity or Pumping Supply)

Elevation above Sea______feet
Extreme Winter Temperatures______°
Hours of Pumping daily________
(24 hours or how many)

Approx. minimum hourly rate of pumpage during winter months________
,, mean daily water pumpage during winter months________

	Range of Diameters.	Approx. Length Miles.	Kinds.	Feet Depth of Laying to			Pipe laid by Contract or by the Company.
				Axis of Pipe.	Bottom of Trench.	Cover over Pipe.	
Supply Mains Distribution Mains Service Pipes							

	* Kind or Character of Soil.	Depth of Frost in Feet in Streets or Highways.		Depth of Frost in Feet in Fields, or Outside of Streets and Highways.
		General.	Extreme.	
Supply Mains Distribution Mains Service Pipes				

* Note: Rock, Hardpan, Clay, Sand or Gravel, Alluvial, mixed.

Approx. percentage in length of pipes below level of ground water______%. Are water pipes laid at stated depth for other reasons than danger of freezing? If so, for what reasons?______

If records have been kept of frozen pipes, kindly quote or abstract them below in the column of remarks, and fill in the following table, if possible :

	Winter of 1904–5.	Winter of 1905–6.	Winter of 1906–7.	Worst Winter in Recollection of Oldest Inhabitant.
Number of cases of frozen supply mains				
,, ,, ,, ,, ,, distrib. ,,				
,, ,, ,, ,, ,, service pipes				
Total length of feet of frozen supply mains				
,, ,, ,, ,, ,, ,, distrib. ,,				
,, ,, ,, ,, ,, ,, service pipes				

Is town or city sewered?______ (Yes or No.) Name______

I also wish to express the hope that the New England Water Works Association will become an active and voting member of the National Fire Protection Association, and that you will send us a voting delegate. That is being done now by a great many associations who are engaged in matters pertaining to construction or equipment in any way allied to fire protection. I thank you for your attention. [Applause.]

Adjourned.

Evening Session, Thursday, September 24.

President Martin in the chair.

The Secretary read the following names of applicants for membership, all properly endorsed and recommended by the Executive Committee:

Active. — Gilbert C. White, Durham, N. C., consulting hydraulic engineer; Albert L. Sessions, Bristol, Conn., president of the Bristol Water Company; Edwin L. Stone, Winchendon, Mass., engaged with the Winchendon Water Works; Albert Blauvelt, Chicago, Ill., associate manager Western Factory Association; Arthur L. Adams, Oakland, Cal., hydraulic engineer; H. J. Deutschbein, Albany, N. Y., superintendent Albany Water Works; W. C. Hoad, Lawrence, Kan., sanitary engineer, Kansas State Board of Health; R. Winthrop Pratt, Columbus, Ohio, chief engineer, Ohio State Board of Health; John S. Keinle, Wilmington Del., chief engineer Wilmington Water Company.

Associate. — East Jersey Pipe Company, New York, manufacturers of lock bar steel pipes and riveted steel pipes.

On motion of Mr. H. N. Parker the Secretary was directed to cast one ballot in favor of the election of the candidates whose names had been read, and, he having done so, they were declared duly elected members of the Association.

Mr. Leonard Metcalf, secretary of the Committee on Awards that have been made for Damages resulting from the Diversion of Water, reported progress for the committee as follows:

Progress Report of Committee on Awards that have been made for Damages resulting from the Diversion of Water.

Under a vote passed by this Association at its last annual con-

vention, held in Springfield, Mass., on September 12, 1907, the sub-joined committee of five was appointed by the President

"To collect data relating to awards that have been made for damages resulting from the diversion of water; also to consider the practicability of joint action with the National Cotton Manufacturers Association, or other organizations of mill owners, relating to the formation of standard rules for computing or assessing damages for the diversion of water."

Your committee has succeeded already in getting together a considerable amount of available data relating to water and water-power diversion suits, but it has seemed desirable to it, in order to broaden the scope of its work and to bring together as far as possible all available material, to send out a postal card inquiry to the members of this Association, as was recently done, asking members to contribute memoranda of any data or cases with which they might happen to be personally familiar, bearing upon the investigation under question, which they might be willing to place at the disposal of the committee. In this way, your committee hopes to acquire data relating to the valuations, sales, or awards for water or water-power diverted under right of eminent domain, of which it might otherwise fail to learn, and incidentally to prevent duplication of information and useless work on the part of active members of the Association in preparing the data. This card of inquiry was sent out with the last notices for this convention, and your committee is glad to be able to report that already a considerable number of encouraging replies have been received. Members who have not yet replied to the circular are urged to do so, in the interest of the Association and in the hope of broadening the scope of the inquiry as far as possible.

Your committee now has under advisement a general set of questions to be forwarded to members who have information along these lines, and have responded favorably to the earlier inquiry of the committee, to assist in the preparation and assembling of the facts in as concise and comparable form as possible. The proposed schedule now under consideration is submitted for friendly suggestion and criticism.

OUTLINE OF PROPOSED SCHEDULE OF QUESTIONS RELATING TO WATER AND WATER-POWER DIVERSION DATA, TO BE SENT TO MEMBERS OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

1. Data of valuation, sale, or award.
2. Amount thereof, exclusive of interest ($).
3. Total amount, including interest and allowances for collateral items.
4. Incorporated name of both parties.
5. Location, town, city, county, and state.
6. Character of privilege.
7. Total area of watershed taken or diverted.
8. Amount of watershed taken or diverted.
9. Amount of water taken or diverted.
10. Theoretical fall taken to which right was claimed.
11. Fall used or developed.
12. Hours per day during which power is used.

In addition to the above fundamental or elementary questions the following questions which will throw valuable light upon the information given will probably be appended in a separate group·

13. Character of development, product of mill, etc.
14. Character of watershed.
15. Cost of coal per 2 000 pounds and of electric current.
16. Is steam used for manufacturing or other purposes?
17. Is water used for any other purposes than for power?
18. Number of wheels installed.
19. Power of wheels.
20. Total steam and electric power development.
21. Total power required to run mill.
22. If supplementary steam or electricity is necessary, state amount.
23. What must be done to improve the privilege, or to develop undeveloped available power there, and cost thereof.
24. Approximate area of mill pond.
25. Approximate depth to which mill pond can be drained.
26. Are there other storage reservoirs upon the watershed? If so, state capacity.
27. Character of control of the storage.
28. What were the controlling factors in the award?
29. Did the award include any allowances other than for the water or water-power?

It has further seemed probable to your committee that for purposes of general standardization or comparison, so far as this

may prove feasible or desirable, the units of value or award in "$—— per square mile of watershed per foot of fall" and the "number of daily million gallons of water diverted per foot of fall," would prove the most satisfactory.

Acting upon the latter part of the vote under which your committee was appointed, after careful consideration of the subject, the conclusion was reached that it is impracticable for the committee "to formulate standard rules for computing and assessing damages for the diversion of water." The committee, with the exception of certain of its members, who modestly refrain from referring to their own work, though hoping to present later a bibliography of the subject, now recalls to the attention of the members of this Association the papers upon this subject published in the JOURNAL of this Association in September, 1907, p. 214 *et seq.*, which in its opinion furnish the best guide to the engineer in methods of computing and assessing damages for the diversion of water, but the committee recognizes that the question is one of law rather than of engineering practice, and that every suit is likely to involve some novel features, and must of course be considered in the light of local circumstances and conditions.

Recognizing the necessity and importance of the subject to the members of this Associaton and the fact that work has but just begun, your committee presents this progress report and asks to be continued.

Respectfully submitted,

CHARLES T. MAIN, *Chairman.*
CHARLES E. CHANDLER.
RICHARD A. HALE.
WILLIAM WHEELER.
LEONARD METCALF, *Secretary.*

Mr. Charles E. Chandler, civil engineer, Norwich, Conn., read a paper entitled "Stream Flow Data."

Mr. Robert E. Horton, hydraulic engineer, Albany, N. Y., submitted a paper, which was read by Mr. Leonard Metcalf, on "The Adjustment of Damages for Stream Diversion by Storage Compensation." Mr. Louis L. Tribus, Mr. Allen Hazen, Mr. T. H. McKenzie, and Mr. Metcalf spoke on the subject.

Mr. Allen Hazen reported for the Committee on Awards that have been made in Water Works Valuation Cases that the only action taken by the committee up to this time, so far as he knew, had been to elect Mr. Desmond FitzGerald chairman. The report was accepted as a report of progress.

Adjourned.

FRIDAY, SEPTEMBER 25, 1908.

This day was devoted to excursions to points of interest in and near Atlantic City.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association at Plymouth, Mass., June 24, 1908.

Present: Messrs. Martin, Collins, Thomas, Bancroft, Sherman, Tower, and Kent.

Eleven applications received and the applicants recommended for membership, viz.:

Dana M. Wood, Frank A. Marston, H. Lester Newhall, Ira C. Forbes, Thomas Gray, James F. Sanborn, Nicholas S. Hill, Jr., Charles L. B. Anderson, C. S. Rex, Jr.,F. C. Hersey, Jr., and Henry A. Young.

Adjourned.

WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association held at Atlantic City, N. J., Thursday, September 24, 1908.

Present: President Alfred E. Martin and members M. N. Baker, George A. King, D. N. Tower, Robert J. Thomas, George W. Batchelder, and Willard Kent.

The following applications were received and approved for membership, viz.:

Gilbert C. White, hydraulic engineer, Durham, N. C.; Albert S. Sessions, president Bristol Water Company, Bristol, Conn.; Edwin L. Stone, Winchendon, Mass.; Albert Blauvelt, associate manager Western Factory Association, Chicago, Ill.; Arthur L. Adams, hydraulic engineer, Oakland, Cal.; H. J. Deutschbeim, superintendent water works, Albany, N. Y.; W. C. Hoad, sanitary engineer, Kansas State of Board Health, Lawrence, Kan.; R. Winthrop Pratt, chief engineer Ohio State Board of Health, Columbus, Ohio; John S. Kieule, chief engineer Water Department, Wilmington. Del.

Associate. — East Jersey Pipe Company, manufacturers of lock bar steel pipe and riveted steel pipe, 90 West Street, New York City.

Adjourned.

WILLARD KENT, *Secretary.*

OBITUARY.

George E. Wilde died very suddenly of heart disease at the office of the Metropolitan Water and Sewerage Board, in Boston, on July 17, 1908. Mr. Wilde was born in Duxbury, Mass., January 29, 1850, and received his early education in an academy in that town. At the age of fourteen he began a seafaring life, which was continued for seventeen years, during which time he made voyages to Spain, Italy, India, Philippine Islands, Germany, Australia, England, and China, and rose from cabin boy to the position of first mate. From 1881 to 1884 he was employed as a foreman in the water department of the city of Worcester, Mass., and during the following six years was employed by A. H. Howland in constructing water-works plants in the middle West. In 1890 he became superintendent of one of these plants at Menominee, Mich., and remained there until 1896, when he returned to Massachusetts and connected himself with the Metropolitan Water Works, the construction of which was then beginning. On December 14, 1897, he was appointed assistant superintendent of the Distribution Department, having charge of the pipe lines and reservoirs of the Metropolitan Water Works within the Metropolitan District, which office he held until his death. He was married in 1879 to Angie C. Joyce, of Duxbury, who, with his son and daughter, survives him. He was elected a member of this Association on June 16, 1886.

Irving T. Farnham, city engineer of Newton, Mass., died September 19, 1908. Mr. Farnham was born in Deposit, N. Y., in 1869. He was graduated from the College of Civil Engineering of Cornell University in 1892. After a few months' service as draftsman for the Elmira Bridge Company, he went to Newton and entered the city engineer's office. He was engaged in im-

portant work for the city until 1899, when he became principal assistant engineer for the Massachusetts Highway Commission. He held this position only about a year, as he became city engineer of Newton in 1900 and remained in that office until his death. During his term of office he had carried out many important pieces of work for the city. He is survived by a wife and four children. Mr. Farnham was a member of the American Society of Civil Engineers and the Boston Society of Civil Engineers. He was elected a member of the New England Water Works Association on December 13, 1905.

BOOK REVIEWS.

TYPHOID FEVER: ITS CAUSATION, TRANSMISSION, AND PREVENTION. By George C. Whipple. xxxvi, 408 pages. 5½ x 8 inches. New York: John Wiley & Sons. 1908. Price $3.00.

The author says in his preface: "The object of this book is to furnish to the members of these two professions [physicians and engineers] a condensed summary of the most important facts that have been learned regarding typhoid fever so far as they relate to the prevention and spread of the disease; to furnish to the student of sanitary science a group of illustrations of some of the leading principles of epidemiology; and to give to the general reader a simple and, it is to be hoped, a clear and correct account of the causation, transmission, and prevention of the disease, and his own responsibility in helping to bring about such conditions of cleanliness that typhoid fever shall soon cease to be a national disgrace."

The members of this Association, to which some of the best papers descriptive of typhoid fever epidemics have been presented, should welcome the present volume. Mr. Whipple has long been known to them as an authority in this field, and as a clear and forceful writer. He has succeeded well in his task, and it is much to be desired that every person who has any responsibility for the quality of a water supply should read this book carefully.

The author concludes that in a general way about 40 per cent. of the typhoid fever in the United States is due to infected water, 25 per cent. to milk, 30 per cent. to ordinary contagion (including transmission by flies), and 5 per cent. to other causes. Thus, in spite of the great improvement in the quality of public water supplies that has been made in recent years, water still remains the most important single cause of the spread of typhoid fever, and it behooves all water-works men to have a clear understanding of the subject, not only that they may suitably protect the water supplies committed to their charge, but also to assist them in placing the responsibility for typhoid cases or even epidemics which may be unjustly charged to the water supply.

From the point of view of the sanitary engineer, it is difficult to imagine a question upon typhoid fever which is not answered in this book. It makes no pretense of treating the subject from a medical standpoint, although the symptoms and the bacteriology of the disease are described with some detail, and in the appendices are described the tests of diagnosis, the bacteriology of the blood, and the methods of examination of water for bacillus typhi.

The book is illustrated by a large number of diagrams and contains a number of tables, particularly of populations and typhoid fever death-rates. There is an excellent index.

NOTES ON HYDRO-ELECTRIC DEVELOPMENTS. By Preston Player. 68 pages. 5 x 7½ inches. New York: McGraw Publishing Company. 1908. Price $1.00.

This little book was written primarily for the purpose of presenting a general treatment of the subject set forth in the title, dealing particularly with the commercial side of the matter, in such a manner as to be acceptable to investors, capitalists, and bankers. It is difficult to see how this book can even in slight measure, fulfill the requirement. It is a carelessly written and very poorly edited book. Its treatment of the subject is so "general" as to be decidedly incomplete, yet technical terms are used so freely and with so little explanation of their meaning that it can hardly be intelligible to the classes for whom it was particularly written.

The titles of the chapters are as follows: Preliminary Determinations; Methods of Procedure; Engineering Examination; The Extent of the Market for Energy; Cost of Energy Manufacture; Central Station Economics; Sale of Electric Energy; Primary and Secondary Powers; Capital Costs.

TRADE PUBLICATIONS.

The Thirty-Ninth Street Sewage Pumping Station (*Chicago, Ill.*). Allis-Chalmers Company, Pumping Engine Department. Bulletin No. 1611, May, 1908.

This bulletin describes the equipment of a sewage pumping station having a capacity of 2 160 000 000 gallons per day, which contains two screw pumps, of the type first used for flushing pumps at Milwaukee, and four vertical centrifugal pumps. The latter are driven by horizontal triple expansion engines, with the cylinders set 120 degrees apart; the screw pumps are driven by vertical triple expansion engines. The boilers, condensers, piping, and coal handling systems are also briefly described

The Manhattan High-Pressure Fire Service System. Allis-Chalmers Company, Pumping Engine Department. Bulletin No. 1614, August, 1908.

This bulletin describes the high-pressure fire system of New York City, about which so much has been said of late. This system consists of main pipes and hydrants independent of the regular water-works system, to which water is furnished under unusually high pressures (300 pounds or more per square inch) by two pumping stations equipped with multi-stage centrifugal pumps, driven by electric motors.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XXII. December, 1908. No. 4.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

THE CONSERVATION OF WATER RESOURCES.

BY M. O. LEIGHTON, CHIEF HYDROGRAPHER, U. S. GEOLOGICAL SURVEY, WASHINGTON, D.C.

[*Read September 23, 1908.*]

It is extremely difficult, if not impossible, to confine the presentation of this subject to those features relating solely to municipal water works. It is so broad and comprehensive that it does not admit of separation into parts, but each field of application comprehends every other. One, and only one, great problem is involved in the conservation of water resources, and when we attempt to separate the particular province of irrigation from that of flood control, or the field of municipal supply from that of water power, or attempt to legislate, to contrive, or to construct for the benefit of one interest exclusively, we often find that we have wrought to the disadvantage of every other. Every detail in the conservation of water for city supply, for example, should be weighed and considered, not exclusively from the single viewpoint, but with due regard for all allied problems of water utilization. The final wise course to be pursued will be that which will serve the greatest number of objects in the wisest way.

We have made little, if any, progress toward the final development of our river systems. Certain improvements have been made, here and there, directed toward a particular and immediate purpose, such as the creation of a navigable channel or the storage of a municipal supply. Beyond this conditions are chaotic, and mature consideration of the matter will show that the principal reason is, that we have, during past years, endeavored to provide

specifically for one interest to the exclusion of another. What, indeed, has been our practice in the development of rivers for navigation? Our engineers have endeavored to provide channels of stated depth at low-water seasons. No other purpose has been confessed. Our water-supply engineers have endeavored to secure storage capacity sufficient to supply municipalities with all the water required, whether the season's drought be long or short. No other purpose have they had in view. Our water-power engineers have endeavored to so develop certain selected sites that they might be made to produce the greatest amount of available energy, and they have thought of little else. Now, in connection with these several developments, had there been foremost in view the ultimate maximum development of the whole river system for present and immediate uses, as well as for those that are bound to come in the far distant future, there must have been an harmonizing of all the various interests involved, so that each step in the subjugation of the river for one or for another purpose would have become a part, so far as physically possible, of the development of the great unit problem.

In the construction of a building, we consider that each stone laid in the wall is not merely a necessary part of the wall at that immediate point, but is a progressive feature of the whole structure, performing its part in the support of the building, and harmonizing itself with the entire plan. So should be each feature of the development of our water resources, and when this is realized and put into practice, we may consider that we have gone a long way toward the final solution of our problems.

It will now be profitable to consider just what we mean by the water resources of the United States. The first impression conveyed is that of a certain amount of water collected on certain drainage basins and conveyed through certain channels into the ocean, and being made to perform, in transit, certain work of benefit to the people. This is not all. Water is not a resource unless it is available for use, and the conditions under which it is so available determine the amount of resource represented. If the water resources of this country are locked up under conditions of ownership or rental which make them either unavailable, or available only at high cost, the resource represented is far less than would

appear upon first consideration. Therefore, we have to consider the condition of ownership and policy of treatment and retention as well as the amount of water and its potential possibilities.

This matter of ownership is one in which we can hardly find cause for congratulation. The United States was abundantly provided with water resources before the American people set foot on the continent. Therefore, we can gain no credit from the actual possession. We begin to be concerned when we consider our stewardship or our administration of those resources, and just there, at the first point where we must be tested, we begin to fail. It appears that we have omitted no expedient by which they could be wasted and placed beyond our control. We find in the third annual report of the New York State Water Supply Commission the following melancholy statement: "We have only to look across our northern border to the Dominion of Canada to see how our mistakes in allowing private interests to acquire natural resources have been avoided by the statesmanship of the Dominion government." This admission was made by a group of gentlemen who had been at work for a year on investigations necessary to collect information relating to the water powers of the state, and to devise plans for the development of such water powers for public use under state ownership and control. This commission was guided in its work by one of our foremost engineers. The character of the work and the excellence of the report are sufficient assurance that this group of gentlemen weighed its words and we may assume that this commission took no particular gratification in admitting the conditions above quoted. What is true in New York state is also true in greater degree in all of the other states of the Union — certainly in no less degree. Therefore, when we examine our water resources for the purpose of determining upon proper public policies, we find that we are obliged to look across an international border to find that condition which we, ourselves, ought to be able to realize. We have been poor stewards. In the one feature of water conservation in which we, as a people, have absolute control, we have failed.

There are many reasons why we have been lax in our public policy and are now liable to pay the price. Not the least among these reasons is the extremely pronounced tendency of the average

American to secure the highest possible profit during the immediate moment, without regard to future consequences and to the exclusion of every civilized duty to future generations. There is something more to be considered than the present generation. All these resources are merely to be held in trust for the future. The President of the United States was right when he said, "You are a very poor citizen if your interest in general welfare does not extend beyond your own generation."

Another important reason for our lax public policy is our apparent lack of ability or willingness to exercise legislative foresight. If we review the history of water legislation during the past century we will find very few acts deliberately framed to provide for the future. We legislate as a rule "from hand to mouth." When an abuse is discovered, remedial legislation follows. When an emergency arises, acts are passed to meet it. When there is a pressing need, new laws come to the rescue. But it is nearly always evident that the emergency is at hand, the abuse past history, and the need urgent. We find very little legislation the intent of which is to provide for future contingencies, or to so remedy present practices as to avoid those contingencies. Now it happens that the conservation of water resources is not a matter that can be treated under ephemeral and emergency legislation Acts passed for this purpose must all be the result of legislative foresight. Their application to the needs of the country may be in the immediate present or generations hence. It is a far cry from such legislation to that enacted under the principles of the famous expression, "Posterity be damned." Summing up the whole matter of our present attitude, one can hardly avoid the reflection that we belong to the tribe of Esau, who for present gratification sold his birthright for a mess of pottage.

There is another reason why we have wasted our water resources. Being born of the tribe of Esau gives us wasteful tendencies, but these may be overcome, as have so many other barbaric habits. The reason why they have not been overcome is that the people as a whole have been so ignorant concerning the water resources. At the first settlement of this continent water resources were so abundant for the few people who came to these shores that there was no necessity for considering their extent. In this respect it is

extremely unfortunate that this continent was not first discovered on its western coast, for then the early settlers would have immediately been confronted with the necessity for considering the water resources. This abundance of water in the East continued to make it unnecessary to take a thought for the morrow through all the days of construction and reconstruction, and it is only within a recent period that this country has become so thickly settled that thoughtful men have deemed it wise to take an account of stock.

Probably 90 per cent. of our people know nothing of our water resources, and the remaining 10 per cent. know all too little. Here is emphasized the need of investigation. If we go back to first principles, it is clear that before we can write we must know the alphabet. Before the present day of steam propulsion came the elementary investigation of Watt and Stephenson; before the present day of electric transmission came the studies of Franklin, Gilbert, Faraday, Volta, and a host of others. The inference is obvious. Before our people can know the extent of their resources, and provide proper legislation for their development and protection, they must know our rivers, their flow, fluctuations, eccentricities, and every feature that contributes to or modifies their utilization as a natural resource. The engineering profession to-day is building great water works of various kinds and basing some of their most important calculations on empirical formulæ. They seek, for example, to determine flow, seasonal distribution, etc., by applying the data determined for one basin to supposedly similar conditions on another. There is much that is not well understood and much more that is understood by a few but has not been popularly disseminated. What, for example, does a water horse-power mean to the average man? It represents no tangible value, as does a barrel of oil or a ton of coal. Therefore, it is something easily and cheaply acquired by private interests. It is something too cheaply purchased and too profitably disbursed. Yet this average man, who knows nothing of the water resources, and to whom a million gallons of water or a thousand horse-power represent merely an indefinite figure, is the one *who shapes our legislative policies and who is responsible for the fact that we must look across an international border for our ideals in water conservation.*

I have said that the average man is responsible for the legislation, but the fact remains that we whose professions lead us into the consideration of water problems are responsible for the ignorance of that average man. We, and we alone, are the individuals who are in a position to teach concerning these matters and to provide for the proper investigations and encourage the proper legislation whereby a wise public policy may be adopted.

If we would sum up the water resources of the United States, we must begin at the sources of supply, namely, the individual drainage areas. Here are catchment basins receiving from the clouds the annual supply of rain. As the rain falls at various times and with varied intensity, so must these basins discharge the water. We have, then, a fluctuating condition, sometimes with rivers high and again with long seasons of low water. The ideal condition would be uniformity in discharge, but this can never be attained. We are not, however, prevented from approaching this ideal condition as closely as possible and, therefore, we are confronted, first of all, by the consideration of floods.

A flood is primarily a waste of water. Although we usually consider it solely as a damage to property, trade, and public comfort, its worst feature arises from the fact that it deprives us of water which might be put to useful purposes. Obviously, the way in which to arrive most nearly to the ideal condition of uniform discharge is to cut off the flood and to increase the low-water flow. Thus we may make both extremes come closer to the mean. To arrive at this end we must save the floods, place them in safe deposit where they can be drawn upon in times of water depression, just as the merchant draws upon his bank account, accumulated during prosperous business periods, at the time when he needs it in periods of financial depression. Our uplands are good for little, as a rule, except for growing of timber and the storage of water. Such uses do not interfere with the purposes of recreation which have become so important in American life, but rather enhance their value for such purposes. Therefore, it seems to the writer that the goal toward which all efforts should be directed should be that condition in which our rivers shall become effectively managed in their discharge. Thus would we not only save the water for beneficial uses, but we would effectively prevent a

large part of the losses due to our annual flood devastations, which amount easily to $100 000 000 per average year.

Having stored our floods, these waters can be released as needed for various purposes below. They can be used to supply cities, to irrigate fields, to assist in maintaining navigable depths in rivers, and, while descending to perform these services, these same waters can be made to turn power wheels for the benefit of manufacturing and commerce. The condition above described is ideal and many good men have regarded it as beyond realization. Doubt has been expressed in spite of the fact that in the few cases in which the idea has been put into practice great success has been realized. Nevertheless, the doubts of able men have prevented thorough investigation of the scheme on a large scale. It is not necessary to actually arrive at the ideal condition in order to receive benefit. There may be, by reason of engineering or natural difficulties, certain losses, certain failures to approach the condition just described, but until we have approached it as nearly as possible, we shall not have performed our work in the conservation of water, nor shall we have discharged our stewardship of this enormous resource.

Instead of conserving our flood waters, we have exercised the utmost ingenuity in increasing their violence. We have, for example, allowed the forests to be cut off and thereby increased the speed with which the precipitated water flows into the river channels. As this subject will be more thoroughly discussed in another paper at this convention, mere mention of the fact will suffice for present purposes. In our public lands we have granted water rights for a small tithe of their value, and in the majority of cases these grants have not resulted in productive development of the rights but merely tied them up, made them unavailable, and thereby assisted their speculative exploitation. By other and similar means and expedients we have established our reputation for improvidence. Unless our policies are reversed, American mankind will pay the price.

The impossibility of suitably covering a subject so great in scope as that implied in the title of this paper is already apparent. Realizing this in the beginning, the author has deemed it wise to avoid discussion of details concerning the extent and regional

distribution of water resources and to present a few thoughts with relation to general public policy. Summarily, it appears that the first step necessary in the conservation of our water resources is a distinct reversal of present public policies and conventional legislation. The second is to prosecute, with zeal, the scientific investigation of the water resources so that facts necessary to their intelligent treatment will be in hand. Third, it is necessary to disseminate broadly this information so that the average man who is responsible for our legislative policies will appreciate the necessity for reversal thereof. This is primarily the duty of engineers and water-works men. They alone possess the means of education. Finally, after the investigations have been concluded and we have at hand facts sufficient for our purposes, it will be necessary to treat the one great subject as a unit, with due regard for all the necessities imposed by the various interests of water utilization, to start our actual conservation work at the sources of supply, and there so to adjust the distribution of water that it may be made to serve in the most useful way all the needs imposed by demands of our present generation and the necessities and demands of those that shall come after.

FOREST CONSERVATION.

BY R. S. KELLOGG, ASSISTANT FORESTER, UNITED STATES FOREST SERVICE.

[*Read September 23, 1908.*]

Ours is primarily a wood-using civilization. Despite the introduction of substitutes for wood in the form of stone, cement, concrete, and steel, our consumption of timber has constantly increased from the earliest days up to the present time. Now our annual requirements exceed forty billion feet of timber, one hundred million cross-ties, four million cords of pulp wood, besides great quantities of other forms of forest products, such as firewood, posts, poles, mine timbers, etc. The per capita consumption of lumber in the United States was 215 board feet in 1850; now it is 470 board feet.

What has been the effect of this tremendous consumption upon our forests? One forest region after another has been attacked. With the exception of Maine, the New England states are cutting mostly second or third growth timber. The box factories there take white pine saplings down to six inches in diameter. The so-called "inexhaustible" white pine forests of Michigan are gone, and millions of acres of cut-over and burned-over land have gone upon the delinquent tax list. Michigan supplied 23 per cent. of the lumber production of the United States in 1880, and less than 5 per cent. of it in 1907. The value of the lumber production in Michigan since 1849 has been 50 per cent. greater than the output of gold in California, and it has all taken place without a thought for the future. The cream of our hardwoods is gone, and it is becoming more and more difficult to get in sufficient quantity the high grades of oak, yellow poplar, ash, and hickory that our great manufacturing industries require. The South's once great supply of yellow pine is rapidly giving way before axe and saw, fire and tornado. Half a generation more will, in most places, see little but remnants left of the Southern forests, and in that time the Pacific coast supplies will be heavily drawn upon.

The prices of forest products have risen more rapidly than those of other commodities. According to the reports of the Bureau of Labor, the quoted prices of the leading kinds of lumber on the New York market have risen twice as much in the last ten years as the average increase in all commodities. This indicates that the supply of timber is not keeping pace with the demand.

Since we cannot get along without timber, it follows that we must take the necessary measures to produce it. The present annual cut of forest products requires at least twenty billion feet of wood. To produce this quantity of wood without impairing the capital stock, our forest land must make an annual increment of 30 cubic feet per acre. Under present conditions of mismanagement and neglect it is safe to say that the average annual increment is less than ten cubic feet per acre for the entire area. This means that *each year's cut* at the present rate takes the growth of more than *three years.* The average age of the trees which are being felled for lumber this year is not less than one hundred and fifty years. The lumberman could not afford to replace them were he blessed with the prospect of unequaled longevity, since such long investments are unprofitable for private capital. In consequence there arises the necessity that the state and national governments, which do not need to look for so high a rate of interest as the private investor, and which are concerned with the promotion of the general welfare, should assume the responsibility of providing a future supply of timber.

The forest area of the United States is sufficient, if rightly managed, to produce eventually timber enough to supply every legitimate need. There is no reason why it should not some day be brought up to the point of yielding an annual increment of more than thirty cubic feet per acre, which will supply the quantity of timber now consumed, and which, if used economically, will be sufficient for a much-increased population.

By way of a concrete example of the necessity for forest preservation, let us note the main facts concerning the proposed Appalachian reserves. The Appalachian region, stretching from New England to northern Georgia, contains 75 million acres of rough or mountain land primarily adapted to the production of hardwood timber, and comprising portions of the watersheds of nearly all of

our great eastern and southern rivers. More than four-fifths of this area has been cut over, and some of it has been cleared, yet it is now furnishing half the annual quantity of hardwood lumber used in the United States. With management according to the principles of modern forestry, the annual growth of timber on this area could eventually be made equal to the quantity of hardwood now annually consumed in the United States.

Some of our greatest and most useful manufacturing industries as conducted at present are absolutely dependent upon a permanent supply of hardwood timber. Among these are cooperage, vehicle and furniture making, the combined annual output of which is valued at upward of four hundred million dollars. The hardwood supply essential for these industries and a multitude of other uses will soon fail unless vigorous action be taken by the national government and the heartiest coöperation be given by the states and individuals most vitally concerned.

Not less essential than for timber production is the proper handling of this great region for watershed protection, the regulation of stream flow to meet the demands of commerce, and the development of power for manufacturing. All the water gathered by the southern Appalachian and White mountains flows to the sea through navigable rivers. In the southern Appalachians there are no natural lakes to gather the flood waters. The only natural factor which tends to equalize the flow of the streams is the forest. In addition to the great property loss which always occurs as the direct result of a flood, there is a still greater though less appreciated loss in soil fertility. In 1896, Professor Shaler said:

"South of Pennsylvania there is, according to my reckoning, based on observations in every state in that upland country, an aggregate area of not less than three thousand square miles where the soil has been destroyed by the complete removal of the woods and the consequent passage of the earthy matter to the lowlands and to the sea. At the rate at which this process is now going on the loss in arable and forestable land may fairly be reckoned at not less than one hundred square miles per annum. In other words, we are each year losing to the uses of man, through unnecessary destruction, a productive capacity which may be estimated as sufficient to sustain a population of a thousand people."

Since that time the cutting of timber, fires and clearing have

greatly accelerated this rate of soil destruction. The property loss resulting from the floods along the Ohio River in January and March, 1907, amounted to nearly ten million dollars, most of which was sustained by the city of Pittsburg. The great loss of life and property which has just occurred in the Carolina floods is too recent to be accurately computed.

The government has already spent or planned to spend some fifty million dollars in an effort to improve the navigability of the streams which have their sources in the southern Appalachians. The total amount of water carried by these streams during the year is amply sufficient for navigation were the flow uniform. The attempt so far has been to *regulate* floods by means of dikes, retaining walls, dams, and locks, and to dredge out resulting bars and flats. This is not enough. It is time to adopt means of *prevention.* The most important of these are the maintenance of forests on the watersheds, and, in addition, the construction of necessary reservoirs to hold the excess run-off and distribute it throughout the year.

The Appalachian streams are of great and increasing importance as sources of power. A fair average of the rental value of the power which it is possible under present conditions to economically develop in the southern Appalachians is nearly forty million dollars a year. The capital invested in the manufacturing enterprises in New England which utilize the power of the streams that rise in the White Mountain region amounts to a quarter of a billion dollars. Water power has a use and value which is in proportion as it is steady and reliable. Such power cannot be obtained from a barren watershed.

The Appalachian region, therefore, is of extreme importance to the East because of its relationship to the hardwood timber supply, navigation, and power. That it must be properly protected cannot longer be questioned. The way to do this is by establishing state and national forests throughout the region, conducted in coöperation with the owners of private timberlands. The interstate relations make the problem primarily one for the general government to undertake. West Virginia cannot be expected to protect the watersheds of the tributaries of the Ohio because Pittsburg and Cincinnati suffer from floods. North

Carolina cannot justly be required to provide its sister states with timber and power. The silt coming from the mountains of eastern Kentucky may be finally deposited in the delta of the Mississippi, and that from western Virginia may choke up the Potomac and the James.

Every argument which is advanced to prove the necessity for protecting watersheds to regulate stream flow applies with redoubled force whenever the run-off from these watersheds is used for city and town supplies.

The national government, then, should acquire the backbone of the great Appalachian ridges, the right management of which is of most importance because of the interstate relations. Other states can establish state forests within their borders, as have New York and Pennsylvania, whose total is nearly two and a half million acres. The West has more than one hundred and sixty million acres of national forests. The East has none. This condition cannot last much longer. The establishment of forest reserves in the Appalachians has been recommended for years by the President, the Secretary of Agriculture, state officials, and a large number of scientific, technical, and trade organizations. The Senate passed the bill providing for these reserves last spring, as it has done before, and the indications are that the House will do so in the near future. When this is done it will mark the most decided advance in the conservation of our natural resources since the establishment of the first National Forest in 1891.

DISCUSSION.

The President. The subject is now open for discussion,

Mr. P. A. Maignen. Is there any tariff on imported wood?

Mr. Kellogg. Yes, sir; there is a tariff of $2 per thousand feet on sawed lumber, but none on logs.

Mr. Maignen. In some European countries, where there are divisions of the forests, no more trees can be cut than are planted to take their place, and in some countries even a private owner cannot cut more from one portion of his land than he plants on some other portion. I was wondering if we could not have some such provision enforced in this country.

Mr. Kellogg. It might be possible, but I don't believe it is very probable. The people of the United States do not like restrictions very much, and what we will have to do, I think, aside from the national government acquiring such land as it can, is to use moral suasion rather than force, though there is a considerable sentiment in favor of the regulation of the cutting of timber on private lands. There is no question but what that sentiment is growing in the United States. The most radical step in that direction was taken in Maine last winter. I do not think the bill was passed by the Legislature of Maine, but the Legislature addressed an inquiry to the state Supreme Court, and the Court decided that it would be constitutional to prohibit the cutting of the smaller sizes of timber upon private land, where the cutting of that timber would seriously affect the public interest, having in mind, for one thing, the relation between forests and stream-flow.

Mr. R. S. Weston. I should like to ask Mr. Kellogg what the prevailing view among forestry experts is regarding the best method of reforesting burned-over areas? Is it considered better to let the wood follow along in natural sequence or to replant?

Mr. Kellogg. That depends to some extent upon the locality and the kind of timber. In general, if conditions are at all favorable, foresters are inclined to regard it as better to let Nature bring back the second growth of timber. It takes longer, but is much cheaper. Forest planting is an expensive operation. It will cost anywhere from five dollars an acre up to plant timber on a commercial scale where it has been destroyed either by fire or cutting. It does not cost you anything if conditions are favorable, except waiting a little longer, to let Nature seed over the area; and so, while there are considerable areas in the United States on which we shall have to reproduce our forests by planting, in general we hope to get our future growth of timber more from natural reproduction, simply because it is so much cheaper.

Mr. Allen Hazen. How old does white pine have to be before it will seed the adjoining area?

Mr. Kellogg. From about twenty years on. It seeds pretty early and grows rapidly. You will find in New England both natural and planted white pine, between thirty and forty years old, that is being cut and sent to the box factories now.

Mr. Hazen. There are sections of New England through which I drive every summer where the white pine has been exterminated because, generations ago, the farmers thought that it was a weed and that they would be better off if they could clear it all from their farms. On this land only birches and woods of less value now grow. I have sometimes thought that if a white pine could be planted here and there, not very near together, they would grow up and seed the whole country in the course of time, without very much expense.

Mr. Kellogg. They probably would.

Mr. Hazen. No one supports more cordially than I the proposition to establish national forest reserves and to have the government acquire the higher land on the mountain ranges that I am so fond of visiting and climbing over in the summer. I believe most thoroughly in propagating the forests and encouraging and extending them, because we shall need the lumber.

But there is one idea that has gone through this discussion of forest preservation about which I am not satisfied, and that seems to be open to reasonable doubt. I refer to the effect of forests in maintaining the flows of our streams for useful purposes. It has been often assumed that the flow of water from a forested area is larger and more constant and more dependable than from a like area of land that is not forested. I have looked in many places, and through a long period of time, for certain, definite evidence upon this point, but I have found nothing satisfactory. If there is really anything of importance in this idea it would seem that it ought to be possible to secure evidence of it of a nature that could not be questioned.

I am somewhat familiar with the Connecticut valley. I remember the hills that I used to climb years ago, as a boy, from which I could see unbroken forest in all directions. Those areas have now been completely cleared of lumber. They are growing up again, to be sure, as fast as they can, but it is certain that the amount of forest on the catchment area of the Connecticut is much less than it was twenty-five years ago. The flows of the Connecticut River have been recorded by gagings extending over many years. From these records, which I have seen, it appears that the flows (and I refer especially to the summer or dry weather flows) have been

greater in recent years since great inroads have been made in the forest areas than they were twenty-five or thirty years ago, when there was certainly much more forest.

If the inquiry is extended to the Merrimac, the Sudbury, the Croton, and other catchment areas for which accurate gagings are available, so far as I know the same results will be found.

I do not think the flows of recent years have been greater because the forests have been cut off, but there is certainly a great lack of evidence that the cutting off of the forests has reduced the flow.

I was greatly interested in Australia last year in finding that some of the engineers and water-works people had exactly the reverse idea from the one which seems to be current here. The catchment areas which serve to supply some Australian cities are covered with forest of a density which can hardly be imagined by one who is only familiar with forests in cool climates; and the idea is held very firmly and by many people that these forests take the water which falls upon them and upon the ground and evaporate it and dissipate it and prevent it from flowing off to the reservoirs that supply the cities; and thousands of acres of those forests upon catchment areas have been ring barked to kill the trees, with the idea of preventing the dissipation of the water by them, and in this way of securing a larger amount to supply the cities.

I inquired for data that would justify this practice, and it is only fair to say that I was as little satisfied as to its being well founded as I am in doubt as to whether the opposite view is well founded in our climate.

I should like to ask Mr. Kellogg how far he has studied this matter, and if he has any figures of any description that are reliable and certain which indicate, or which even tend to indicate, that the run-off from forested areas is greater or more certain than from like areas that are not forested.

Mr. Kellogg. There are a great many things that complicate the matter, as Mr. Hazen has evidently found out on going into it a little. The only way to ever answer the question on a scientific basis is to have a long series of various kinds of records, — records of the actual condition of the watershed so far as its cover is concerned: whether it is timbered or cut over or burned over or grassed; an accurate knowledge of what the geological formation

is; what the shape of the drainage basin is; an accurate record of the precipitation through a series of years; and an accurate record of the run-off or gagings of the streams. It seems to me we must have all this evidence in order to answer the question, because all these factors influence the run-off, and we do not have such complete knowledge, so far as I know, upon any drainage basin in the United States. If I am wrong, I hope Mr. Hazen or Mr. Parker will correct me. Because we do not know these things at present, we have to draw our conclusions from what meager data we do have, and also somewhat from theoretical considerations. It does look from some data as though there were a close connection, while other data do not seem to show anything either way, — I will say that frankly. The figures I read here a little while ago indicate pretty strongly that there has been an increase in the run-off of certain of our important rivers, and we know that during the period covered by the record the only change which has taken place on the watershed has been the cutting off of a considerable quantity of timber. The records which I read here, which extend in some cases over a period as long as seventy years, show an increase in the number and duration of floods in such rivers as the Ohio and the Cumberland.

The theoretical considerations are something like this. We know that where we have a forest for a long time upon an area which is not damaged by fire, we get a gradual accumulation from decaying trees, leaves, and undergrowth which makes a blanket over the surface of the ground, and that blanket is somewhat in the nature of a sponge. It would certainly seem that when water falls upon such a blanket it would be retarded in its flow and more would sink into the ground than if we had a barren watershed covered only with rock, or possibly with gravel or very hard soil,

I do not think it is at all common to claim that the total run-off from a watershed is likely to be increased by having a forest upon it. The total run-off in a series of years may be just as great from a forested watershed as from a barren watershed, but it would seem that the run-off would be regulated, that the floods might be strung out further and not reach as high a stage, and that the low-water stage might not be so low in the case of a protected watershed as in the case of a non-protected watershed.

This matter which Mr. Hazen brought up in connection with Australian watersheds, that is, the loss of water by its being taken up and transpired into the atmosphere by the forest, probably has quite a little in it; but, on the other hand, such observations as have been made, particularly in Germany, indicate that there is no more moisture transpired by forests than there is by a covering of grass or some other kind of vegetation. But it certainly does seem reasonable that a forest must have a good deal of restraining influence upon the run-off, and it is unquestionable that the run-off from a well-protected watershed does not carry nearly as much silt as it carries from an unprotected watershed. We have case after case of the most striking kind, particularly through the South, where, when the timber has been removed, erosion of the face of the country has immediately set in, and set in where it did not exist before; and that means that your water is polluted to a certain extent, and it most certainly means that your water course is filling up with silt.

Mr. Frank L. Fuller. Mr. President, this matter which Mr. Hazen has spoken of I think is very important, and I have often thought of it myself, because we all know how the roots of trees will run down into the soil in search of moisture. We have seen the roots of elm-trees running into sewer pipes and into all sorts of moist places, apparently seeking to get to water. I noticed some time ago, in a covered reservoir, where some cracks had been made by a settlement in the bank, causing a slight aperture through the concrete, which was covered with earth, grass roots had gone down three or four feet, I should think, to get at the moisture underneath. It was rather surprising to me that those roots should have extended down so far.

It seems to me that some experiments should be made, and I wonder that they have not been made, as to how much moisture a tree will take up. It would seem as though a tree might be planted in some sort of an inclosed watertight basin, supplied with water, and in some way the amount of moisture taken up by the tree and evaporated gotten at. Of course any amount of water which is evaporated into the air is so much lost to the soil, and, therefore, lost to the drainage area. It may fall again on the same drainage area in the form of rain, but it may not.

There is one other thought which occurs to me, and that is in connection with the retention of snow in the forests. Mr. Kellogg did not mention that matter, but he can probably give us some information in regard to it. Oftentimes we go into the woods in New England as late, perhaps, as the latter part of May, and find considerable snow retained in the shady portions of the forest. That snow, of course, will gradually get into the streams, and will cause much less variation in the flow of the stream than it would have caused if it had all gone off suddenly, as it would have done if the area had been unwooded. It seems to me there is one point where the advantage of a wooded area is considerable.

Mr. Kellogg. That is what ordinarily occurs, but let me give an instance on the other side which will bear out the point Mr. Hazen made that there is a great diversity of opinion on these subjects. A man told me not long ago that in his opinion the forests in the southern Appalachian hills are really responsible for the floods. His idea was that the snow collected in the forest during the winter and then melted and went out all at once in the spring, and that made the floods.

Mr. Fuller. I suppose that in case of a warm rain the snow would go out fast, and perhaps some of our heaviest floods are caused in that way, — by the combined effect of the melting snow and the rain, — but it would seem as though the snow being retained and held back by the forest was an advantage.

Mr. Kellogg. In general it would seem as though that were so, but I cannot say offhand what the European observations have been, so far as the effect of the retention of snow upon the subsequent run-off is concerned. The European observations, as I recollect, show, as I said a minute ago, that the amount of water transpired by forest is at least no greater, and in some cases less, than by other forms of vegetation. You get transpiration everywhere where there is vegetation, because water performs its function in plant life principally as it is transpired. It acts there somewhat as in the development of water power. It is only as water passes from one condition to another that its use is developed.

Mr. Hazen. Mr. Kellogg has described the humus blanket, so-called, and its supposed effect in maintaining flow. I think that

his principle is right, but it is my idea, after giving the matter considerable attention, that the real blanket which holds the winter water and gives it up in summer is the layer of glacial drift that is found on nearly all of our northern streams, and also the older deposits with similar physical properties which occur along the Atlantic coast to the southward, and other similar pervious deposits in other parts of the country. I know that this material is often many feet in depth and is pervious and has a great capacity for taking up water and holding it and giving it out slowly, and we know, from the records of rainfall and of run-off, that this material, or some material, holds back the rainfall in the months of excess and gives it out in the months of deficiency, and it seems to me that this pervious, gravelly material has so much greater capacity in this respect than any possible humus layer could have that the influence of the humus, if any, must be trifling in amount in comparison with that of the sand and gravel blanket.

Mr. W. C. Hawley. It may be of interest to call attention to the fact that the flood in the Allegheny River last year was the most serious flood they ever had, and as the result of the drought which western Pennsylvania has been experiencing for some two or three months, the streams in that locality are to-day lower than they have been for a period of perhaps forty or fifty years. I haven't any exact data on that, but statements have been published in the newspapers within the last week or ten days to that effect. Of course the forests on the Allegheny River have been to a considerable extent removed. The banks have been encroaching more or less upon the stream in the vicinity of Pittsburg, also, from year to year, as they have been built upon, and this may account in part for the flood last year reaching so unusual a height.

Mr. Albert Blauvelt. I should like to ask the reader of the paper whether any of the data concerning water flow have been made out on the idea that the question is one of relation of the forest to the character of the earth's surface. I don't know that I make myself clear. We know perfectly well that a tree itself takes up a great deal of water and evaporates it into the atmosphere. That water never reaches the ground at all. It also holds a great deal of snow in the winter time, which melts on the tree in warm days and returns to the atmosphere, wholly irrespective of the

breathing action of the tree or moisture drawn from the ground. We know very well if we had a surface made of sheet tin, with convenient flow points, like the roof of a house, and had sponges on it instead of forest, we would retain considerable water, but otherwise we would immediately have a rapid run-off. Now I am asking for information whether the studies have gone into a consideration of the thought that the real point may be, not whether forest is present or absent, not whether the soil is water-tight on the surface or is capable of retaining great quantities of moisture, as the last speaker mentioned, but whether it is not a question of what are the relations between those two. In other words, if you have a surface soil capable of quick drainage and incapable of retaining water, then you must have forests. And cannot some of these discrepancies be explained on the ground that where there is a lack of water you have a surface which has failed to retain the water? In other words, that you can have a well-regulated flow either with plenty of forest or a good absorbent surface to the earth, but you must have one or the other, and you will get into trouble if you fail as to both.

Mr. Kellogg. I think that is a point well stated. The records which have been taken up to the present time I do not believe have been from that standpoint, and that is particularly true of the earlier records, because we began this work in rather a haphazard fashion, without taking all the factors into consideration. When the first records on some of these streams were taken seventy years ago nobody thought of forestry. That didn't get started in the United States until sixteen or seventeen years ago, and it has only been since that time we have been considering some of these questions. We are just now getting at the heart of them. Heretofore we have had only partial records, in some cases of the rainfall and in some cases of the condition of the watershed, and when we try to tie them up we find that they were not taken with the object in view of correlating these different things, because we hadn't got that far into the subject.

Mr. Blauvelt. Personally, I believe that we must have a sponge either in the forest or on the ground.

Mr. Kellogg. I should think so, and that suggests a question I wanted to ask in regard to the New England streams. Does any-

body here remember how far south the line of glacial drift extends? My remembrance is that it is not south of New York.

A Member. It goes to New Brunswick, N. J.

Mr. Hazen. And there are tertiary deposits beyond that, which have the same characteristics, extending down through New Jersey.

Mr. M. N. Baker. It is quite evident from the discussion we have had this afternoon that there is much need of giving careful attention to the subjects which have been before us. The question of the transpiration of forest growths is discussed in Fernow's "Economics of Forestry." (1902.) Some years ago, Mr. C. C. Vermeule and the late George W. Rafter, and others, discussed forests and run-off before the American Forestry Association. The latest contribution to the subject has just been made public in an advance copy of a paper by Lieut.-Col. H. M. Chittenden. (Proceedings of the American Society of Civil Engineers, for September, 1908.)

I think the consensus of opinion here agrees quite well with the consensus of opinion generally, as far as one can gather it, and that is that forests have comparatively slight influence upon rainfall, but more influence, however, upon the run-off, and that their influence upon the run-off is more in equalizing the flow, particularly floods. The forest floor, or blanket, or sponge, as it has been called, has a very great influence upon violent fluctuations of stream flow.

The effect of forests upon the distribution of the run-off as related to the snowfall is also very material. Some years ago Prof. L. G. Carpenter, of Fort Collins, Colo., brought out a very interesting bulletin dealing with this matter of snowfall retention in forested area. On June 24 of this year, in company with the American Society of Civil Engineers, I was up at about an elevation of 11 660 feet, on one of the railways which is being built from Denver through to Salt Lake City. As we got up toward that altitude we saw very unmistakable evidences of the effect of forest upon the snow. In the heavily wooded areas along the railroad track there were snow banks many feet in thickness, whereas out where the sun would strike, and where there was a southern exposure, there was practically no snow at all.

Mr. H. N. Parker. Mr. President, it seems to me that this discussion gives point to a portion of Mr. Leighton's paper, in which he said it was necessary for us to take up these problems as a whole. In the past a lack of proper legislation and possible lack of breadth of view on the part of investigators has led us to consider each question by itself, so while we have had gaging stations, for instance, established on the rivers, it may be that they have not been established at places where at the same time observations could be made of the effect of cutting off the forest and the work which the forestry bureau was doing. It seems to me we have got to proceed in a businesslike as well as scientific sort of way in the investigation of all these matters connected with the conservation of our natural resources, and, as Mr. Leighton said, educate the ordinary citizen up to the point where he will insist on his state legislature, his municipal government, and the national government appropriating funds to carry on this work through a sufficient length of time to get definite results.

Prof. Edward W. Bemis. Mr. President, I think this discussion has been very valuable. It may be worth while to bear in mind that whatever doubt we may have as to the effect of forests upon the fall of water, there is no doubt, as Mr Hazen has expressed it, as to the importance of the forest policy of the government in relation to the timber supply, and there seems to be some degree of warrant for the opinion that it has a probable effect upon climate and upon the rainfall; so that while we are still having some doubts as to the full effect of the forests upon the water supply, we are sure enough of our other points to uphold the policy of the government for a large development of government forests and a thorough investigation by the government of the forestry question.

I believe Europe must have exact data, such as have been called for to-day and not produced, upon the flow of water in rivers. I can hardly imagine that the French and German governments could have carried on their works as many years as they have without getting very definite data, which no one here seems to be able to quote, on that one point of the flow of water. But, as I say, that is one point only, and we may still have our doubts on that and have no doubt whatever on the general policy of the government on the subject.

It has seemed to me for a long time that the decades to come will look upon the present administration as having performed its absolutely greatest service, of all the many services it has performed, in its conservation of our natural resources. That, it seems to me, we can have very little doubt upon. It has been the great stock argument, as you are doubtless aware, of many of the economists, that the forestry question is the absolute proof of the mistake of the individuals, and of the philosophy of Herbert Spencer and others, in their theory that the interests of the individual and the interests of society are identical. The forestry question has been often cited as the absolute proof of the falsity of that opinion, because the individual's interests do not run generally over twenty or thirty years, while it takes from forty to one hundred years to develop the economic value of the forests, and, therefore, only society in its organized capacity is able to look upon the question broadly. The individual cannot look on it broadly because the individual wants to reap in his own lifetime. And in so far as it is not purely a question of lumber or timber which may be grown in the lifetime of the individual owner, and so far as there is any effect on climate, or on the rainfall, and broadly on the country, that, of course, is altogether a benefit to society at large, and, therefore, only society at large can take an interest in the subject.

I think there is enough evidence already at hand to warrant the idea that, independent of any party affiliations, we cannot too strongly approve large acquisitions of government forests. One of the beauties of this moment is that it is independent of all partisan spirit. The movement is becoming a general one, but does not seem yet to overcome the opposition of certain selfish interests in the House of Representatives. I think, however, in the country at large, the sentiment is getting to be almost overwhelming, and it is for us to make it more so if possible. I have enjoyed this discussion very much indeed, and I hope that we may be able, or Mr. Kellogg may be able, to turn to the French and German data, for I am sure that there must be such, on the point which has been especially discussed to-day.

A Member. When I was a small boy there used to be a great deal said about the cutting off of the forests, that it was going to

decrease the rainfall; I don't hear anything said about that subject nowadays. I have had occasion to work somewhat on a small scale and argue from the smaller to the greater. It would seem as if it were reasonable, perhaps, that if we cut off the forest we thereby open up more and more freely the channel ways for the water, and that, therefore, the water would get quicker to its main outlet and would seem to be increased in quantity, there would be greater floods, and we would get the impression that there was a greater total amount; while with the trees in large areas there is less free access to the water channels and, therefore, a greater regulation of the flow.

I should like to know whether there has been in the forestry examinations anything on the first point, that is, a decreased actual total rainfall. I have noticed this on small tracts. We have had occasion to look up many cases of claims for damages due to development of localities. People have come in and been almost black in the face over the damage done by floods. They have said, " All my ancestors, and the people from whom I bought the property, never knew such floods; we have more water coming down to-day than ever came before." That is what I have heard day after day. Now, what is the fact? The fact is, that the rainfall statistics show the same averages, fluctuating up and down, up and down, up and down, but practically the same that they were fifty years ago; but the development of the region, the building of streets, the draining of swamps, the removal of small tracts of forest, allows the water to flow more quickly. I imagine that that is going to be one of the serious points in connection with our forestry conservation. If we can control the water by dams and reservoirs of various sizes, by improved lands and some forest, we will get the same result from the point of view of the conservation of the water that we would from actual forest lands.

Mr. Parker. We all know the effect of a wagon track through a forest region, and have seen on the mountain side how the water will seek such a track and flow down rapidly through that free channel way. There are very many things which complicate this problem which we are now discussing.

Mr. George A. King. I should like to ask Mr. Kellogg if he has any figures as to the waste of lumber and wood in forest fires, and

if that is not one of the most serious problems in the protection of the forests.

Mr. Kellogg. It is unquestionably one of the most serious problems we have, and it is more serious from the standpoint of private forestry than any other thing. We haven't any reliable data upon the annual loss from forest fires in the United States. It has been estimated at from $25 000 000 to $100 000 000. We intend within the next month or two to begin the collection of statistics on the damage by forest fires in the United States in 1908. The fires this year throughout the United States have been worse than they have any year since the noted fires in Minnesota in 1894, and we are going to get all the information possible in regard to them.

There is absolutely no question that fire is one of the most serious hindrances to the practice of forestry by individuals and by large companies and corporations in the United States, but there is also absolutely no question that fire can, in the main, be prevented. It is being done almost completely in the national forests. We haven't entirely eliminated fires, but we have almost, so that the amount of timber which is destroyed by fire each year in the national forests is almost negligible as compared with the amount of timber in those forests. On the other hand, it was true, up to the time of the establishment of the national forests in the Rocky Mountain region, that enormous quantities of timber were destroyed by fire. Fires are preventable, but with the exception of what has been done by the national government and by two or three states, they have not been prevented.

Mr. Morris Knowles. I had occasion some time ago to look up some foreign records. In a translation by one of the army officers (Gen. Godfrey Weitzel, of the United States Engineer Corps) of a paper by Gustav Wex, reference is made to observations upon some of the streams of Germany and Austria, running back some one hundred to one hundred and fifty years. While the data were not entirely complete, conclusions were drawn as to the relation of forests to run-off. It appears that floods had increased for those areas where the forests had been cut away, but no mention was made in regard to rainfall or its distribution, or of many other conditions; simply the fact was given that the forests had

been cut off and that certain stream flows showed that for recent periods there were notably higher floods and lower summer flows than before.

I believe the distribution of the rainfall is one of the most important items, and upon this we have had but little data until recent years.

The late flood in the Ohio Valley, which was one of the largest ever recorded, was from a rainfall upon a limited area, mostly upon one tributary, namely, the Monongahela. It backed up into the Allegheny somewhat, and produced in the Ohio River a marked flood. The distribution of the rainfall as to the season and as to the different portions of the watershed, and as to the state of the soil and vegetation, must have a great effect upon the surface run-off.

Until facts can be secured along this line, where there are so many different opinions, no definite conclusions can be reached. We need more information, our discussions are based upon insufficient data, and I hope that this consideration of the subject will cause us all to use our influence with those who vote and appropriate the public moneys for the uses of such departments of our government, to see that there shall be liberal allowances to conduct such investigations. We may not realize the benefit in our day; as Professor Bemis has well said, it is a work for society as a whole, because of its long-continued effect; but by securing the data we shall have done something for the benefit of those who come after us.

Mr. A. A. Reimer. Our city of East Orange, N. J., has gone into this matter within the last year and started on our watershed the development of a nursery and plantation. We have about eight hundred acres, and of this, possibly 30 per cent. is a sort of rough forest. We have not gone at this question with the view of conserving the water supply primarily, for it will probably have no direct effect upon that at present, as our supply is entirely from artesian wells, but we have gone at it from the standpoint of lumber values, not figuring for to-day, of course, but for the future. We are making a very thorough study of the question. The state has lent us its expert, Mr. Alfred Gaskill, who is our general adviser, and we are following out his plans to the letter, and hope that in the course of ten years we will have as hand-

some a stand of fine lumber as can be found in our region. We have it in mind that this will be an object lesson, and we hope eventually that others around us will see the good result, and thereby we may receive a benefit to our water supply, as we realize that if there is anything in the idea of the retention of the rainfall by forests, artesian supplies will receive the same benefit that surface supplies will, and if forest areas can be developed within from three to ten miles of us on land which to-day is absolutely worthless for anything but forest, we believe we will receive in that way a benefit to our water supply. So we are not entirely unselfish, either from the standpoint of water supply or lumber, but at present the main point is the lumber supply, and we are developing a tract of land that in the next thirty to fifty years will furnish the finest kind of lumber.

Mr. M. N. Baker. It ought to be noted, I think, in connection with this discussion, that for some years past a number of municipalities and a few private water companies have been going quite extensively into the same line of work that has been mentioned by the last speaker. Four or five years ago I gathered quite a lot of information regarding forestry works on water-works drainage areas. I should suppose that since that day there must have been many municipalities, and perhaps a few more companies, who have joined ranks of those who at that time had taken up the work. As I remember it, there were half a dozen or some such number of rather notable instances of forestal work on drainage areas of American water supplies. In England considerable work of this kind has been done, and some very interesting reports have been made on forestry operations by the Liverpool works.

STREAM FLOW DATA.

BY CHARLES E. CHANDLER, CIVIL ENGINEER, NORWICH, CONN.

[Read September 24, 1908.]

At the November, 1907, meeting in Boston, I presented some tables of stream flows which were, with the accompanying explanations, printed in the December, 1907, JOURNAL.

Later I had tables prepared showing the flow of other streams,

TABLE No. 10.*

SUDBURY RIVER AT FRAMINGHAM. DRAINAGE AREA, 75 SQUARE MILES.

Monthly flows in second-feet per square mile, arranged chronologically.

Year.	Jan.	Feb.	Mch.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1875	0.159	2.315	2.482	4.718	1.838	1.346	0.497	0.612	0.321	1.000	2.015	0.903
1876	0.995	2.116	6.862	5.094	1.761	0.343	0.283	0.627	0.285	0.361	1.683	0.702
1877	1.019	1.469	7.448	3.703	2.153	0.924	0.312	0.187	0.092	0.977	2.193	1.995
1878	2.800	3.814	5.426	2.516	2.158	0.782	0.199	0.736	0.249	0.799	2.619	4.916
1879	1 083	2.647	3.605	4.821	1.723	0.640	0.243	0.611	0.218	0.109	0.318	0.716
1880	1.733	2.765	2.126	1.808	0.796	0.271	0.273	0.184	0.124	0.157	0.318	0.271
1881	0.642	2.392	6.195	2.392	1.493	2.070	0.428	0.229	0.305	0.287	0.611	1.199
1882	1.920	3.718	4.392	1.342	1.998	0.818	0.133	0.086	0.474	0.463	0.324	0.487
1883	0.518	1.598	2.492	2.088	1.450	0.464	0.178	0.122	0.141	0.288	0.317	0.299
1884	1.540	4.397	5.857	4.415	1.594	0.644	0.346	0.397	0.068	0.129	0.271	1.431
1885	1.910	2.095	2.433	2.808	2.067	0.659	0.096	0.372	0.187	0.519	1.822	1.816
1886	2.260	7.428	3.185	3.013	1.114	0.314	0.179	0.146	0.182	0.225	1.041	1.578
1887	4.006	4.377	4.437	4.053	1.561	0.640	0.178	0.331	0.172	0.294	0.570	0.995
1888	1.629	3.011	5.009	4.093	2.526	0.652	0.182	0.587	1.786	3.093	4.267	4.708
1889	4.305	1.850	2.071	2.182	1.361	1.011	0.980	2.216	1.274	1.903	3 003	3.467
1890	1.941	2.366	5.636	2.900	2.114	0.878	0.166	0.204	0.708	3.515	1.879	1.541
1891	4.669	5.393	6.889	3.708	0.902	0.639	0.231	0.252	0.314	0.325	0.472	0.842
1892	2.893	1.459	3.024	1.347	1.948	0.662	0.331	0.433	0.354	0.195	1.088	0.750
1893	0.671	2.386	5.020	3.287	4.460	0.681	0.244	0.280	0.167	0.343	0.494	1.242
1894	1.082	1.533	3.462	2.537	1.299	0.648	0.249	0.323	0.232	0.579	1.293	1.108
1895	1.600	0.837	3.728	3.901	0.984	0.270	0.357	0.354	0.138	2.133	4.296	2 767
1896	1.677	4.140	5.937	2.311	0.557	0.617	0.147	0.088	0.600	0.916	1.019	1.016
1897	1.307	1.651	3.968	2.290	1.416	1.488	1.018	0.914	0.282	0.145	1.406	2.450
1898	2.534	4.675	4.028	2.829	1.928	0.820	0.357	1.713	0.571	1.795	3.072	2 783
Av.	1.871	2.935	4.405	3.090	1.717	0.762	0.317	0.500	0.385	0.856	1.516	1.616

* Note that numbers of tables are consecutive with those in the previous paper (JOURNAL, December, 1907, p. 464).

and both sets with explanations were printed in the 1908 Proceedings of the Connecticut Engineers' Association. I suggested to Mr. Kent that these additional tables might be printed in some number of the JOURNAL if it were thought best, and he desired that I present them here.

Three of the additional tables presented contain Sudbury data. The tables presented to the Connecticut Association included the thirty-two years, 1875 to 1906. The months showing minus flows were something of a stumbling block. Mr. FitzGerald has written me that the passing of so much Nashua River water through the Sudbury watershed during the years since 1898 makes the deduced

TABLE No. 11.

SUDBURY RIVER AT FRAMINGHAM. DRAINAGE AREA, 75 SQUARE MILES.

Monthly flows in second-feet per square mile arranged in order of magnitude for each year.

Year.	1	2	3	4	5	6	7	8	9	10	11	12
1875	0.159	0.321	0.497	0.612	0.903	1.000	1.346	1.838	2.015	2 315	2.482	4.718
1876	0.283	0.285	0.343	0.361	0.627	0.702	0.995	1.683	1.761	2.116	5.094	6.862
1877	0.092	0.187	0.312	0.924	0.977	1.019	1.469	1.995	2.153	2.193	3.703	7.448
1878	0.199	0.249	0.736	0.782	0.799	2.158	2.516	2.619	2.800	3.814	4.916	5.426
1879	0.109	0.218	0.243	0.318	0.611	0.640	0.716	1.083	1.723	2.647	3.605	4.821
1880	0.124	0.157	0.184	0.271	0.271	0.273	0.318	0.796	1.733	1.808	2.126	2.765
1881	0.229	0.287	0.305	0.428	0.611	0.642	1.199	1.493	2.070	2.392	2.392	6.195
1882	0.086	0.133	0.324	0.463	0.474	0.487	0.818	1.342	1.920	1.998	3.718	4.392
1883	0.122	0.141	0.178	0.288	0.299	0.317	0.464	0.518	1.450	1.598	2.088	2.492
1884	0.068	0.129	0.271	0.346	0.397	0.644	1.431	1.540	1.594	4.397	4.415	5.857
1885	0.096	0.187	0.372	0.519	0.659	1.816	1.822	1.910	2.067	2.095	2.433	2.808
1886	0.146	0.179	0.182	0.225	0.314	1.041	1.114	1.578	2.260	3.013	3.185	7.428
1887	0.172	0.178	0.294	0.331	0.570	0.640	0.995	1.561	4.006	4.053	4.377	4.437
1888	0.182	0.587	0.652	1.629	1.786	2.526	3.011	3.093	4.093	4.267	4.708	5.009
1889	0.980	1.011	1.274	1.361	1.850	1.903	2.071	2.182	2.216	3 003	3.467	4.305
1890	0.166	0.204	0.708	0.878	1.541	1.879	1.941	2.114	2.366	2.900	3.515	5.636
1891	0.231	0.252	0.314	0.325	0.472	0.639	0.842	0.902	3.708	4.669	5.393	6.889
1892	0.195	0.331	0.354	0.433	0.662	0.750	1.088	1.347	1.459	1.948	2.893	3.024
1893	0.167	0.244	0.280	0.343	0.494	0.671	0.681	1.242	2.386	3.287	4.460	5.020
1894	0.232	0.249	0.323	0.579	0.648	1.082	1.108	1.293	1.299	1.533	2.537	3 462
1895	0.138	0.270	0.354	0.357	0.837	0.984	1.600	2.133	2.767	3.728	3.901	4.296
1896	0.088	0.147	0.557	0.600	0.617	0.916	1.016	1.019	1.677	2.311	4.140	5.937
1897	0.145	0.282	0.914	1.018	1.307	1.406	1.416	1.488	1.651	2.290	2.450	3.968
1898	0.357	0.571	0.820	1.713	1.795	1.928	2.534	2.783	2.829	3.072	4.028	4.675
Av.	0.198	0.283	0.450	0.629	0.813	1.086	1.355	1.648	2.250	2.810	3.584	4.911

flow less precise than in previous years. The years since 1898 contain all the minus months. On this account the Sudbury tables presented to-day include only the twenty-four years, 1875 to 1898, and probably the flow of these years is more useful than the flow of the thirty-two years. This makes the tables of permanent value without further modification.

The present tables include the Nashua flows for ten years, 1897 to 1906, arranged chronologically, in order of magnitude yearly, and in order of magnitude for full term. This table will be modified by the addition of future data.

The Merrimac data for seventeen years, 1890 to 1906, measured weekly, are given in order of magnitude. This table will be modified by both future and previous records when they are available.

This table is accompanied by one giving the number of weeks in the average of these years that any given flow has occurred and at any development the percentage available. It seems to me that these Merrimac tables, prepared from data furnished by Mr. Hale, are well worth the labor they cost.

I hope that next year Mr. Hale will give us the Merrimac data chronologically and in order of magnitude for each year, and for the full term from a much earlier date than 1890 up to 1908, and that other engineers having such data regarding other streams will give us all the benefit of them, at least chronologically.

Now I wish the limitations of this and preceding papers to be distinctly understood. There is no attempt to make a rule for determining the available flow of every or any particular stream under all circumstances. The aims and objects are:

1. To put in print for the use of all members, data heretofore not in print, or available to but few members.

2. To put these data in form of second-feet per square mile instead of second-feet for the particular place where the measurements were made.

3. To arrange these data not only chronologically, which in many cases is the most useful form, but also in order of magnitude for each year.

4. To also arrange the data in order of magnitude for full term, which is an unusual, but more precise, method of eliminating all unavailable storm flows in water-power developments.

5. The available percentage of the flow for any development is added in some cases.

These are basic tables. They can be used without modification for twenty-four hour per day use. For ten or eleven hours the results at different seasons of the year must be modified according to the opportunities on the stream for night storage and other local conditions.

The papers by Messrs. Main, Herschel, and Hale, printed in the September, 1907, JOURNAL, leave little to be desired in the way of methods for the application of stream flow data to especial cases.

TABLE No. 12.

SUDBURY RIVER AT FRAMINGHAM. DRAINAGE AREA, 75 SQUARE MILES.

Monthly flows in second-feet per square mile arranged in order of magnitude of whole term, 1875 to 1898 inclusive.

	1	2	3	4	5	6	7	8	9	10	11	12
1	0.068	0.182	0.283	0.357	0.612	0.837	1.114	1.594	1.948	2.392	3.072	4.392
2	0.086	0.184	0.285	0.357	0.617	0.842	1.199	1.598	1.995	2.392	3.093	4.397
3	0.088	0.187	0.287	0.361	0.627	0.878	1.242	1.600	1.998	2.433	3.185	4.415
4	0.092	0.187	0.288	0.372	0.639	0.902	1.274	1.629	2.015	2.450	3.287	4.437
5	0.096	0.195	0.294	0.397	0.640	0.903	1.293	1.651	2.067	2.482	3.462	4.460
6	0.109	0.199	0.299	0.428	0.640	0.914	1.299	1.677	2.070	2.492	3.467	4.669
7	0.122	0.204	0.305	0.433	0.642	0.916	1.307	1.683	2.071	2.516	3.515	4.675
8	0.124	0.218	0.312	0.463	0.644	0.924	1.342	1.713	2.088	2.526	3.605	4.708
9	0.129	0.225	0.314	0.464	0.648	0.977	1.346	1.723	2.095	2.534	3.703	4.718
10	0.133	0.229	0.314	0.472	0.652	0.980	1.347	1.733	2.114	2.537	3.708	4.821
11	0.138	0.231	0.317	0.474	0.659	0.984	1.361	1.761	2.116	2.619	3.718	4.916
12	0.141	0.232	0.318	0.487	0.662	0.995	1.406	1.786	2.126	2.647	3.728	5.009
13	0.145	0.243	0.318	0.494	0.671	0.995	1.416	1.795	2.133	2.765	3.814	5.020
14	0.146	0.244	0.321	0.497	0.681	1.000	1.431	1.808	2.153	2.767	3.901	5.094
15	0.147	0.249	0.323	0.518	0.702	1.011	1.450	1.816	2.158	2.783	3.968	5.393
16	0.157	0.249	0.324	0.519	0.708	1.016	1.459	1.822	2.182	2.800	4.006	5.426
17	0.159	0.252	0.325	0.557	0.716	1.018	1.469	1.838	2.193	2.808	4.028	5.636
18	0.166	0.270	0.331	0.570	0.736	1.019	1.488	1.850	2.216	2.829	4.053	5.857
19	0.167	0.271	0.331	0.571	0.750	1.019	1.493	1.879	2.260	2.893	4.093	5.937
20	0.172	0.271	0.343	0.579	0.782	1.041	1.533	1.903	2.290	2.900	4.140	6.195
21	0.178	0.271	0.343	0.587	0.796	1.082	1.540	1.910	2.311	3.003	4.267	6.862
22	0.178	0.273	0.346	0.600	0.799	1.083	1.541	1.920	2.315	3.011	4.296	6.889
23	0.179	0.280	0.354	0.611	0.818	1.088	1.561	1.928	2.366	3.013	4.305	7.428
24	0.182	0.282	0.354	0.611	0.820	1.108	1.578	1.941	2.386	3.024	4.377	7.448
Av.	0.138	0.235	0.318	0.491	0.694	0.981	1.395	1.773	2.149	2.692	3.783	5.367

TABLE No. 13.

South Branch Nashua River at Clinton. 119 Square Miles.

Monthly flows in second-feet per square mile, arranged chronologically.

	Jan.	Feb.	Mch.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1897	1.232	1.440	4.270	2.525	1.800	1.828	2.231	1.386	0.528	0.377	1.984	3.521
1898	2.418	2.530	4.778	3.137	2.151	1.281	0.514	2.049	1.045	2.334	3.358	3.189
1899	3.236	1.687	4.295	5.224	1.344	0.869	0.548	0.365	0.387	0.379	0.665	0.555
1900	1.232	6.271	5.759	2.444	2.139	0.894	0.336	0.304	0.197	0.437	1.354	2.429
1901	0.803	0.551	4.205	7.711	4.222	1.525	0.738	0.792	0.495	1.001	0.799	5.002
1902	2.579	2.168	6.176	3.341	1.595	0.635	0.452	0.459	0.372	1.471	0.982	2.859
1903	1.957	3.300	5.297	3.463	0.880	3.297	0.966	0.734	0.580	1.065	0.981	1.476
1904	1.020	1.434	4.653	4.617	2.317	1.179	0.769	0.549	0.764	0.538	0.530	0.680
1905	1.959	0.700	4.648	2.502	0.688	0.838	0.565	0.497	1.900	0.567	0.684	1.575
1906	1.757	1.588	2.878	3.263	2.371	1.831	1.127	0.915	0.428	0.820	1.160	1.229
	1.819	2.167	4.696	3.823	1.951	1.418	0.825	0.805	0.670	0.899	1.250	2.252

TABLE No. 14.

South Branch Nashua River at Clinton. 119 Square Miles.

Monthly flows in second-feet per square mile arranged in order of magnitude by years.

	1	2	3	4	5	6	7	8	9	10	11	12
1897	0.377	0.528	1.232	1.386	1.440	1.800	1.828	1.984	2.231	2.525	3.521	4.270
1898	0.514	1.045	1.281	2.049	2.151	2.334	2.418	2.530	3.137	3.189	3.358	4.778
1899	0.365	0.379	0.387	0.548	0.555	0.665	0.869	1.344	1.687	3.236	4.295	5.224
1900	0.197	0.304	0.336	0.437	0.894	1.232	1.354	2.139	2.429	2.444	5.759	6.271
1901	0.495	0.551	0.738	0.792	0.799	0.803	1.001	1.525	4.205	4.222	5.002	7.711
1902	0.372	0.452	0.459	0.635	0.982	1.471	1.595	2.168	2.579	2.859	3.341	6.176
1903	0.580	0.734	0.880	0.966	0.981	1.065	1.476	1.957	3.297	3.300	3.463	5.297
1904	0.530	0.538	0.549	0.680	0.764	0.769	1.020	1.179	1.434	2.317	4.617	4.653
1905	0.497	0.565	0.567	0.684	0.688	0.700	0.838	1.575	1.900	1.959	2.502	4.648
1906	0.428	0.820	0.915	1.127	1.160	1.229	1.588	1.751	1.831	2.371	2.878	3.263
	0.436	0.592	0.734	0.930	1.041	1.207	1.399	1.815	2.473	2.842	3.874	5.229

TABLE No. 15.

South Branch Nashua River at Clinton.

Monthly flows in second-feet per square mile arranged in order of magnitude of whole term, regardless of the years.

	1	2	3	4	5	6	7	8	9	10	11	12
1	0.197	0.452	0.551	0.700	0.869	1.065	1.386	1 751	2.151	2.525	3.300	4.648
2	0.304	0.459	0.555	0.734	0.880	1.127	1.434	1.800	2.168	2.530	3.341	4.653
3	0.336	0.495	0.565	0.738	0.894	1.160	1.440	1.828	2.231	2.579	3.358	4.778
4	0.365	0.497	0.567	0.764	0.915	1.179	1.471	1.831	2.317	2.859	3.463	5.002
5	0.372	0.514	0.580	0.769	0.966	1.229	1.476	1.900	2.334	2.878	3.521	5.224
6	0.377	0.528	0.635	0.792	0.981	1.232	1.525	1.957	2.371	3.137	4.205	5.297
7	0.379	0.530	0.665	0.799	0.982	1.232	1.575	1.959	2.418	3.189	4.222	5.759
8	0.387	0.538	0.680	0.803	1.001	1.281	1.588	1.984	2.429	3.236	4.270	6.176
9	0.428	0.548	0.684	0.820	1.020	1 344	1.595	2.049	2.444	3.263	4.295	6.271
10	0.437	0.549	0.688	0.838	1.045	1.354	1.687	2.139	2.502	3.297	4.617	7.711
	0.358	0.511	0.617	0.776	0.955	1.220	1.518	1.920	2.336	2.949	3.859	5.552

TABLE No. 16.

Nashua River at Clinton. 119 Square Miles.

Comparison of available flow averaged by three different methods.

Chronologically.			Order of Magnitude by Years.			Order of Magnitude of Whole Term.		
Month.	Flow.	Flow Available.	No.	Flow.	Flow Available.	No.	Flow.	Flow Available.
September	0.669	0.669	1	0.436	0.436	1	0.358	0.358
August	0.805	0.794	2	0.592	0.579	2	0.511	0.498
July	0.824	0.809	3	0.734	0.697	3	0.617	0.587
October	0.899	0.866	4	0.930	0.844	4	0.776	0.706
November	1.250	1.100	5	1.041	0.918	5	0.955	0.825
June	1.418	1.198	6	1.207	1.015	6	1.220	0.980
January	1.819	1.398	7	1.399	1.111	7	1.518	1.129
May	1.951	1.453	8	1.815	1.285	8	1.920	1.296
February	2.167	1.525	9	2.473	1.504	9	2.337	1.436
December	2.251	1.546	10	2.842	1.596	10	2.949	1.580
April	3.823	1.808	11	3.874	1.768	11	3.859	1.740
March	4.696	1.881	12	5.229	1.881	12	5.552	1.881

TABLE No. 17.

MERRIMAC RIVER AT LAWRENCE. DRAINAGE AREA, 4 452 SQUARE MILES.

1890 to 1896. Weekly data arranged in order of magnitude for full term in second-feet per square mile.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	0.271	0.386	0.414	0.434	0.459	0.476	0.491	0.500	0.515	0.534	0.548	0.565	0.581	0.602	0.615	0.640	0.663	0.689
2	0.284	0.387	0.415	0.434	0.461	0.477	0.491	0.501	0.516	0.534	0.549	0.565	0.581	0.602	0.617	0.641	0.663	0.692
3	0.325	0.390	0.415	0.437	0.461	0.477	0.492	0.501	0.517	0.535	0.550	0.566	0.582	0.604	0.618	0.642	0.665	0.692
4	0.335	0.393	0.416	0.437	0.461	0.479	0.492	0.502	0.519	0.536	0.551	0.568	0.583	0.604	0.619	0.644	0.665	0.693
5	0.339	0.394	0.418	0.439	0.463	0.480	0.493	0.505	0.519	0.536	0.553	0.569	0.584	0.604	0.621	0.644	0.666	0.694
6	0.342	0.396	0.419	0.440	0.465	0.482	0.493	0.505	0.521	0.536	0.553	0.570	0.589	0.605	0.624	0.645	0.668	0.695
7	0.344	0.396	0.420	0.440	0.466	0.482	0.493	0.505	0.521	0.536	0.553	0.570	0.591	0.607	0.624	0.645	0.669	0.699
8	0.345	0.397	0.422	0.440	0.466	0.482	0.494	0.506	0.524	0.536	0.555	0.571	0.591	0.607	0.625	0.648	0.672	0.701
9	0.359	0.399	0.422	0.441	0.466	0.483	0.494	0.508	0.524	0.539	0.555	0.573	0.597	0.607	0.626	0.652	0.673	0.704
10	0.364	0.401	0.423	0.444	0.467	0.487	0.494	0.508	0.525	0.541	0.555	0.574	0.597	0.608	0.626	0.654	0.676	0.706
11	0.368	0.403	0.423	0.446	0.467	0.487	0.495	0.508	0.525	0.541	0.556	0.574	0.598	0.609	0.629	0.655	0.677	0.706
12	0.369	0.405	0.423	0.447	0.468	0.488	0.495	0.508	0.526	0.542	0.556	0.575	0.600	0.613	0.629	0.655	0.679	0.707
13	0.372	0.405	0.424	0.449	0.469	0.489	0.496	0.512	0.529	0.543	0.557	0.575	0.600	0.613	0.634	0.656	0.681	0.707
14	0.374	0.406	0.430	0.451	0.469	0.489	0.498	0.513	0.530	0.544	0.557	0.578	0.601	0.614	0.635	0.657	0.685	0.710
15	0.380	0.406	0.431	0.455	0.470	0.490	0.498	0.514	0.532	0.546	0.557	0.578	0.601	0.614	0.636	0.659	0.686	0.711
16	0.383	0.409	0.432	0.457	0.470	0.490	0.499	0.514	0.533	0.546	0.560	0.578	0.601	0.614	0.636	0.660	0.687	0.712
17	0.385	0.411	0.432	0.458	0.472	0.491	0.500	0.515	0.533	0.548	0.564	0.579	0.601	0.615	0.639	0.660	0.688	0.715
Average,	0.349	0.399	0.422	0.444	0.466	0.484	0.494	0.507	0.524	0.540	0.555	0.572	0.593	0.608	0.627	0.650	0.674	0.702

TABLE No. 18.

Merrimac River at Lawrence. Drainage Area, 4 452 Square Miles.

1890 to 1906. Weekly data arranged in order of magnitude for full term.

	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	0.716	0.743	0.763	0.790	0.826	0.865	0.899	0.934	0.991	1.045	1.114	1.160	1.231	1.300	1.355	1.420	1.485	1.577
2	0.720	0.743	0.764	0.792	0.837	0.865	0.900	0.935	0.994	1.046	1.118	1.161	1.234	1.302	1.359	1.421	1.486	1.577
3	0.721	0.744	0.766	0.794	0.839	0.867	0.902	0.947	0.999	1.053	1.121	1.161	1.235	1.307	1.367	1.423	1.486	1.580
4	0.721	0.744	0.772	0.795	0.841	0.869	0.902	0.951	1.000	1.054	1.123	1.163	1.244	1.313	1.367	1.429	1.490	1.583
5	0.722	0.745	0.773	0.795	0.845	0.870	0.903	0.953	1.001	1.067	1.126	1.169	1.249	1.313	1.370	1.430	1.493	1.590
6	0.722	0.745	0.773	0.795	0.847	0.874	0.903	0.966	1.004	1.073	1.127	1.173	1.251	1.316	1.375	1.433	1.502	1.590
7	0.724	0.751	0.774	0.800	0.848	0.878	0.910	0.968	1 007	1.079	1.130	1.181	1.252	1.316	1.387	1.438	1.504	1.592
8	0.726	0.752	0.775	0.802	0.849	0.879	0.910	0.971	1.009	1.083	1.135	1.195	1.260	1.319	1.394	1.442	1.517	1.595
9	0.726	0.753	0.780	0.802	0.853	0.886	0.911	0.972	1.015	1.086	1.138	1 197	1.268	1.319	1.394	1.443	1.519	1.596
10	0.727	0.755	0.780	0.807	0.855	0.886	0.913	0.972	1.017	1.092	1.142	1.198	1.272	1.319	1.398	1.444	1.530	1.597
11	0.729	0.756	0.781	0.809	0.858	0.888	0.915	0.973	1.025	1.095	1.142	1.204	1.275	1.319	1.400	1.452	1.532	1.600
12	0.729	0.756	0.781	0.809	0.859	0.888	0.925	0.974	1.029	1.098	1.143	1.204	1.287	1.327	1.412	1.457	1.536	1.604
13	0.730	0.756	0.783	0.809	0.859	0.888	0.925	0.977	1.034	1.098	1.144	1.208	1.291	1.328	1.413	1.458	1.545	1.608
14	0.731	0.757	0.783	0.810	0.861	0.889	0.928	0.980	1.035	1.101	1.148	1.210	1.292	1.333	1.414	1.477	1.545	1.608
15	0.731	0.758	0.784	0.813	0.863	0.891	0.928	0.985	1.036	1.108	1.148	1.211	1.295	1.335	1.414	1.477	1.548	1.615
16	0.733	0.759	0.788	0.821	0.864	0.894	0.928	0.989	1.039	1.110	1.149	1.218	1.296	1.344	1.416	1.477	1.548	1.619
17	0.740	0.760	0.788	0.825	0.864	0.895	0.929	0.991	1.041	1.110	1.157	1.222	1.296	1.353	1.417	1.485	1.569	1.622
Average	0.726	0.752	0.777	0.804	0.851	0.881	0.914	0.961	1.016	1.082	1.136	1.190	1.266	1.321	1.391	1.447	1.520	1.597

TABLE No. 19.

Merrimac River at Lawrence. Drainage Area, 4 452 Square Miles.

1890 to 1906. Weekly data arranged in order of magnitude for full term.

	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
1	1.626	1.785	1.895	2.017	2.128	2.280	2.431	2.565	2.786	3.017	3.323	3.639	4.199	4.519	5.088	5.765
2	1.634	1.802	1.902	2.019	2.133	2.283	2.432	2.568	2.823	3.053	3.356	3.661	4.217	4.562	5.095	5.908
3	1.634	1.804	1.903	2.026	2.169	2.289	2.440	2.571	2.830	3.084	3.384	3.681	4.244	4.565	5.111	5.941
4	1.639	1.825	1.928	2.048	2.173	2.294	2.443	2.598	2.832	3.092	3.389	3.683	4.261	4.608	5.122	6.310
5	1.686	1.831	1.929	2.049	2.202	2.319	2.457	2.619	2.853	3.096	3.415	3.690	4.278	4.636	5.168	6.364
6	1.687	1.833	1.929	2.050	2 203	2.322	2.461	2.631	2.865	3.103	3.424	3.747	4.291	4.637	5.242	6.426
7	1.697	1.846	1.935	2.055	2.204	2.350	2.472	2.676	2.891	3.119	3.433	3.762	4.300	4.681	5.267	6.436
8	1.701	1.851	1.941	2.056	2.205	2.371	2.473	2.687	2.915	3.123	3.445	3.835	4.320	4.701	5.270	6.470
9	1.702	1.858	1.943	2.060	2.217	2.372	2.486	2.701	2.930	3.124	3.446	3.894	4.339	4.718	5.274	6.767
10	1.708	1.861	1.946	2.075	2.226	2.376	2.502	2.714	2.953	3.134	3.454	3.942	4.342	4.723	5.307	7.260
11	1.716	1.874	1.969	2.077	2.231	2.377	2.507	2.723	2.955	3.147	3.476	3.944	4.375	4.723	5.335	7.361
12	1.718	1.883	1.969	2.078	2.231	2.388	2.508	2.726	2.982	3.148	3.478	3.950	4.378	4.734	5.340	7.891
13	1.725	1.885	1.981	2.091	2.239	2.391	2.509	2.729	2.986	3.150	3.481	3.966	4.468	4.837	5.387	7.900
14	1.734	1.889	1.990	2.098	2.246	2.392	2.530	2.735	3.005	3.193	3.493	3.969	4.469	4.884	5.392	8.237
15	1.759	1.890	1.993	2.104	2.254	2.394	2.531	2.746	3.014	3.231	3.510	3.981	4.471	5.007	5.530	8.622
16	1.764	1.892	2.005	2.115	2.259	2.400	2.539	2.751	3.014	3.234	3.520	4.060	4.475	5.044	5.585	9.036
17	1.781	1.895	2.014	2.116	2.270	2.406	2.558	2.781	3.015	3.303	3.529	4.168	4.511	5.061	5.725	9.043
Av.	1.701	1.853	1.951	2.067	2.211	2.353	2.487	2.678	2.921	3.138	3.444	3.857	4.349	4.744	5.308	7.161

TABLE No. 20.

MERRIMAC AT LAWRENCE. 1890 TO 1906.

Second-feet per square mile.

Development.	Average Available.	Weeks.		Available per ct. of Development.
		Short.	Full.	
0.3	0.300	0	52	100
0.4	0.399	2	50	100
0.5	0.492	7	45	98
0.6	0.572	13	39	95
0.7	0.642	17	35	92
0.8	0.705	21	31	88
0.9	0.762	24	28	85
1.0	0.813	26	26	81
1.1	0.861	28	24	78
1.2	0.906	30	22	76
1.3	0.947	31	21	73
1.4	0.986	33	19	70
1.5	1.022	34	18	68
1.6	1.055	36	16	66
1.7	1.085	36	16	64
1.8	1.114	37	15	62
1.9	1.142	38	14	60
2.0	1.168	39	13	58
2.1	1.193	40	12	57
2.2	1.215	41	11	55
2.3	1.236	41	11	54
2.4	1.256	42	10	52
2.5	1.275	43	9	51
2.6	1.292	43	9	50
2.7	1.309	44	8	48
2.8	1.325	44	8	47
2.9	1.340	44	8	46
3.0	1.354	45	7	45
3.1	1.367	45	7	44
3.2	1.380	46	6	43
3.3	1.391	46	6	42
3.4	1.400	46	6	41
3.5	1.413	47	5	40
3.6	1.423	47	5	39
3.7	1.432	47	5	38
3.8	1.442	47	5	37
3.9	1.451	48	4	37
4.0	1.458	48	4	36
4.1	1.466	48	4	36
4.2	1.474	48	4	35
4.3	1.482	48	4	35
4.4	1.488	49	3	34
4.5	1.494	49	3	33
4.6	1.500	49	3	33
4.7	1.506	49	3	32
4.8	1.510	50	2	32
4.9	1.514	50	2	31
5.0	1.518	50	2	30

A GLANCE AT THE WATER SUPPLY OF PHILADELPHIA.

BY JOHN C. TRAUTWINE, JR., CIVIL ENGINEER, PHILADELPHIA, PENN.

[*Read September 23, 1908.*]

INTRODUCTION.

Now that the New England Water Works Association has ventured so far out of its latitude as to hold its convention in a suburb of Philadelphia, it seems not inappropriate that some mention should be made of a water-works enterprise the inception and progress of which have greatly exercised some of the inhabitants of that city.

I have been asked to present a statement of the "progress and present condition" of the Philadelphia filtration plant; but, in order to do this satisfactorily, it may be well to give, first, an outline of the works in general.

With the same object in view, I find myself tempted to volunteer also a bit of the *history* of the Philadelphia water supply, even at the risk of indulging in some personal reminiscences, and thus fighting some of my own battles o'er again.

EARLY CONDITIONS.

The public water supply of Philadelphia has always been drawn either from the Schuylkill River alone or from the Schuylkill and Delaware rivers, the Schuylkill being a tributary of the Delaware and entering that stream at the lower end of the city.

The Schuylkill rises in the anthracite coal regions of Pennsylvania, about 100 miles above Philadelphia, and has a watershed of about 1 900 square miles. The Delaware rises in the south-eastern part of New York state, a little north of Port Jervis, where New York, New Jersey, and Pennsylvania meet. Its watershed, above Philadelphia, has about 8 000 square miles, and is about 180 miles long, from north to south, and in general from 20 to 70 miles wide from east to west.

Prior to 1854 the city of Philadelphia covered only about two square miles, being comprised within the nearly rectangular area bounded by the Delaware River on the east, by the Schuylkill

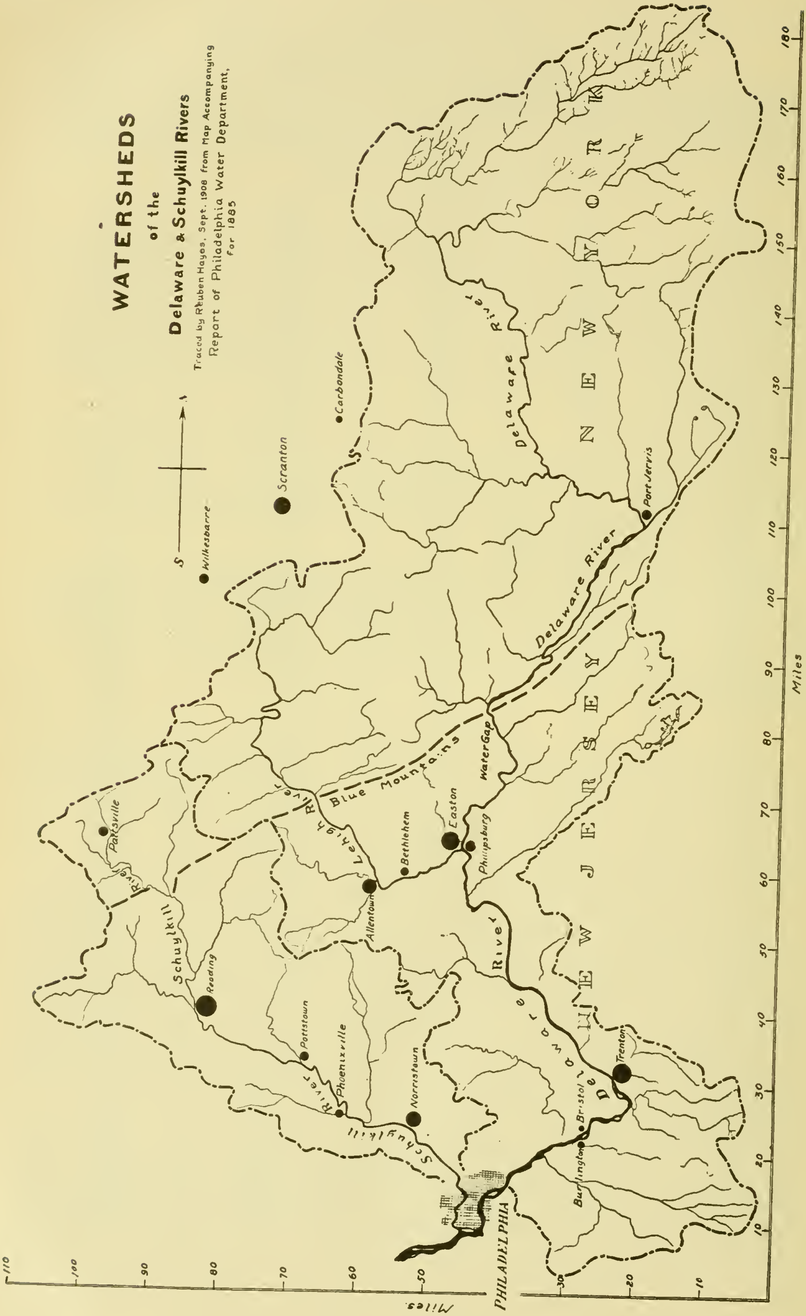

WATERSHEDS
of the
Delaware & Schuylkill Rivers
Traced by Reuben Hayes, Sept. 1908 from Map Accompanying
Report of Philadelphia Water Department,
for 1885
Wilkesbarre
Scranton
Carbondale
Pottsville
Schuylkill River
Reading
Pottstown
Phoenixville
Norristown
Allentown
Bethlehem
Lehigh River
Blue Mountains
Easton
Phillipsburg
Water Gap
Delaware River
Port Jervis
Trenton
Bristol
Burlington
PHILADELPHIA
NEW YORK
NEW JERSEY
Miles

FIG. 1.

River on the west, by Vine Street on the north, and (appropriately) by South Street on the south. The distance between rivers is about two miles, and the distance between Vine and South streets is about one mile. Beyond these limits lay the "districts" of Kensington, Northern Liberties, Spring Garden, etc., on the north; Southwark, Moyamensing, etc., on the south.

About the close of the eighteenth century, say 1795 to 1800, the city was repeatedly scourged by yellow fever, which drove its well-to-do inhabitants to the adjacent hills or to distant places and left the poor in town to bear it as best they could.

Even in those early days, some connection was suspected between the water supply and the spread of such diseases, for these visitations of yellow fever gave rise to active agitation for an improved and public water supply, the supply hitherto having been taken from wells and cisterns.

Scott's Geographical Dictionary, published in 1805, says: "The water of those parts of the city which are most thickly inhabited . . . had become so corrupt by the multitude of sinks and other receptacles of impurity, as to be almost unfit to be drank."

As in later days, all manner of rival schemes were brought forward and were soon in lively conflict. Among these stood out prominently the proposition of the Delaware and Schuylkill Canal Company, which proposed to tap the Schuylkill River at Norristown, fourteen miles above the city, and to construct a navigation canal from that point down the east bank of the Schuylkill River to Fairmount, and thence across the country, just north of the city, to the Delaware. This concern proposed to tap its main canal at Broad Street and to bring a branch canal, for water supply, to a pond or reservoir to be constructed on "Broad Street extended," at what is now Callowhill Street, just north of the then city limits, whence another canal was to lead down Broad Street, across the city, to South Street, and to supply canals, or at least gutters, on the east and west streets. This was to be a gravity supply, in the true and extreme sense of the word, the citizens being expected to take their supplies by main force from these surface canals. In the canal company's proposition, the introduction of a supply under pressure was reserved for future discussion.

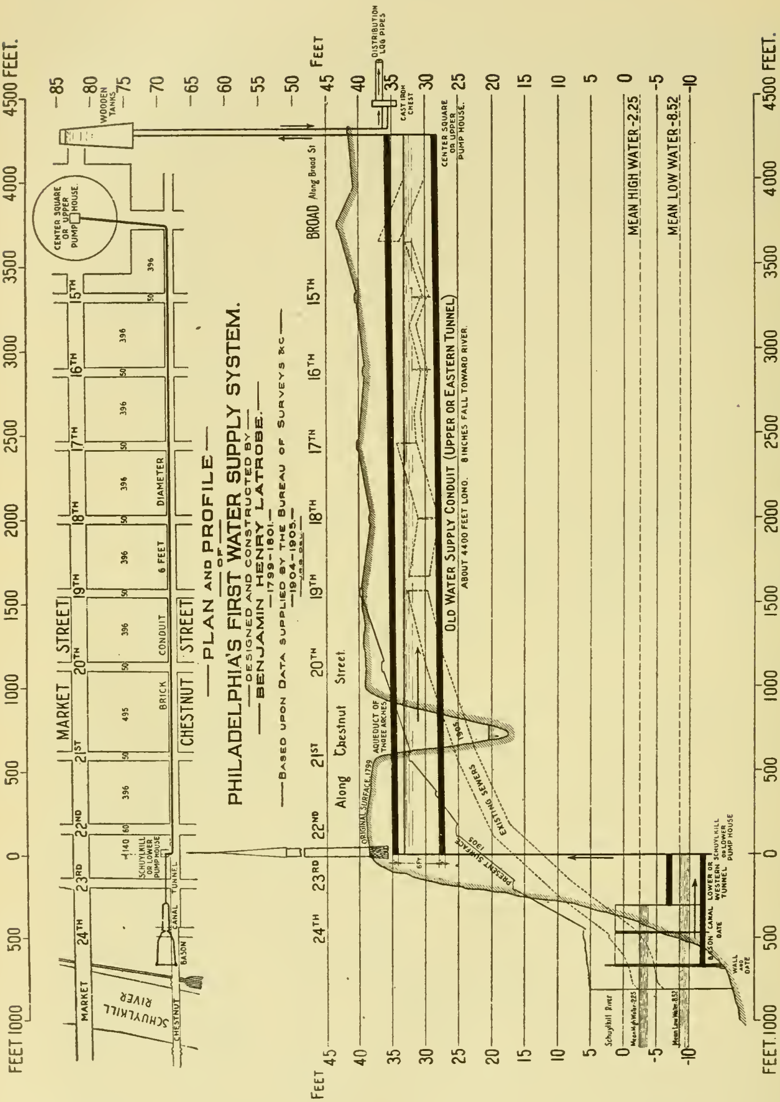


Fig. 2. Philadelphia's First Water Supply System.
Devised and Constructed by Benjamin Henry Latrobe, 1799-1801.
Plan and Profile.

Another prominent project was that of Benjamin Franklin, who left a sum of money to be expended in bringing the waters of the Wissahickon Creek to the city.

Finally, however, the project of Benjamin Henry Latrobe (who

refers to himself as being " the only successful architect and engineer " in America at that time) prevailed and was carried to execution in 1801. (See portrait, Plate I.)

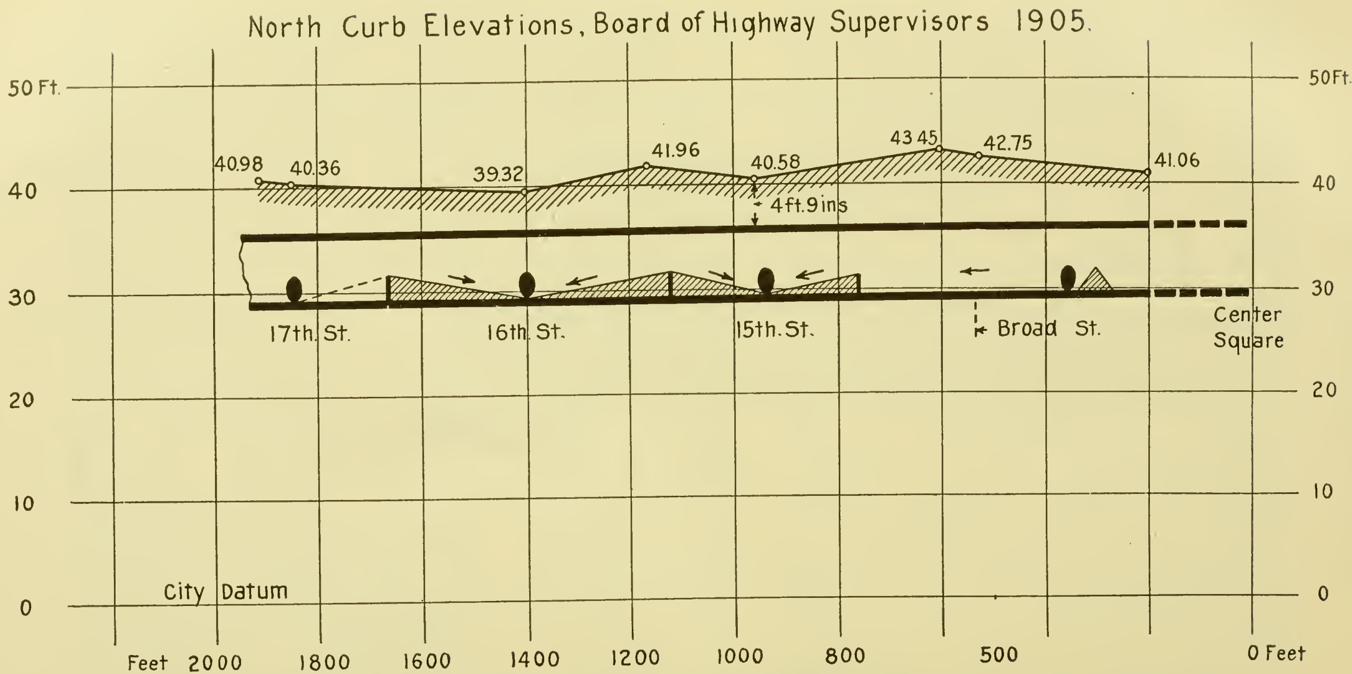
The Schuylkill was tapped on the east side, at Chestnut Street, and its waters were led, by gravity, to the pump well of a steam station located upon the site of a British redoubt, on high ground on the north side of Chestnut Street, just west of Twenty-Second Street, or about one block east of Chestnut Street bridge. (Plate II, Fig. 1.) Here the surplus power of the engine was rented out to run a rolling and slitting mill in an adjacent building.

This station lifted the water into a six-foot brick conduit, which ran along the north side of Chestnut Street to Broad Street, and there turned abruptly and ran northward to a second station in Center Square, the site of the present City Hall. Here the water was again pumped, this time into overhead tanks, whence it flowed through log pipes to the distribution. (See Fig. 2, and Plates II and III.)

West of about Seventeenth or Eighteenth Street, the grading down of Chestnut Street has removed the old conduit, but east of Seventeenth Street it is still in place. During comparatively recent years it has been used for purposes of sewerage, a low dam being constructed across it, about the middle of each block, and false bottoms placed in it, sloping each way from the dams to the sewers on the north-and-south streets at the ends of the block, as shown in Fig. 3. The conduit (so much as remained of it) was thus made to serve as a series of short feeders to the sewers running north and south. In April, 1906, the old conduit was cut through, where the City Hall looks down South Broad Street, by the excavations for the subway since constructed.

In a report to the American Philosophical Society, in 1803, Latrobe mentions the two engines of the Philadelphia system, two in New York, and one in Boston, five in all, as being " the only engines of any considerable powers which, as far as I know, are now at work in America." This enables us to form some idea of the prodigiousness of the work involved in the tiny first waterworks of Philadelphia.

The earliest boilers were of wood, but these were shortly followed by cast iron, and afterward by plate iron boilers. The prin-



OLD 6 FT. BRICK AQUEDUCT IN BROAD AND CHESTNUT ST'S. AS USED FOR SEWERAGE.

FIG. 3.

Benjamin Henry Latrobe,

Engineer of Philadelphia's first Water Works, 1799-1801.

FIG. 1. SCHUYLKILL PUMPING STATION, PHILADELPHIA.
BUILT 1799–1801.

(From a water-color sketch by Mumford.)

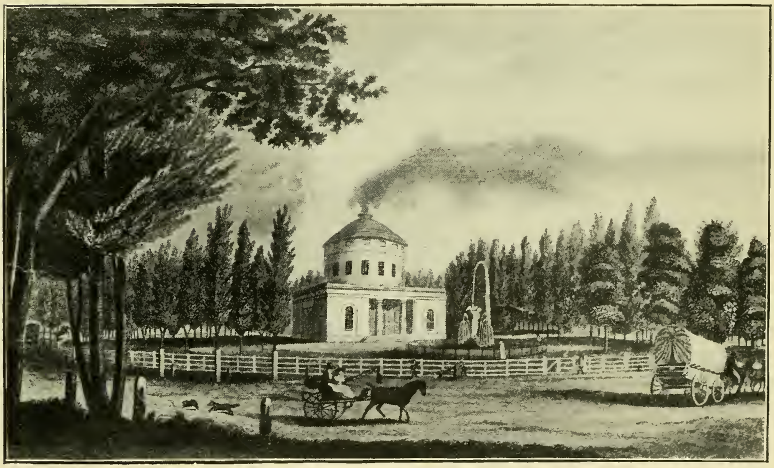
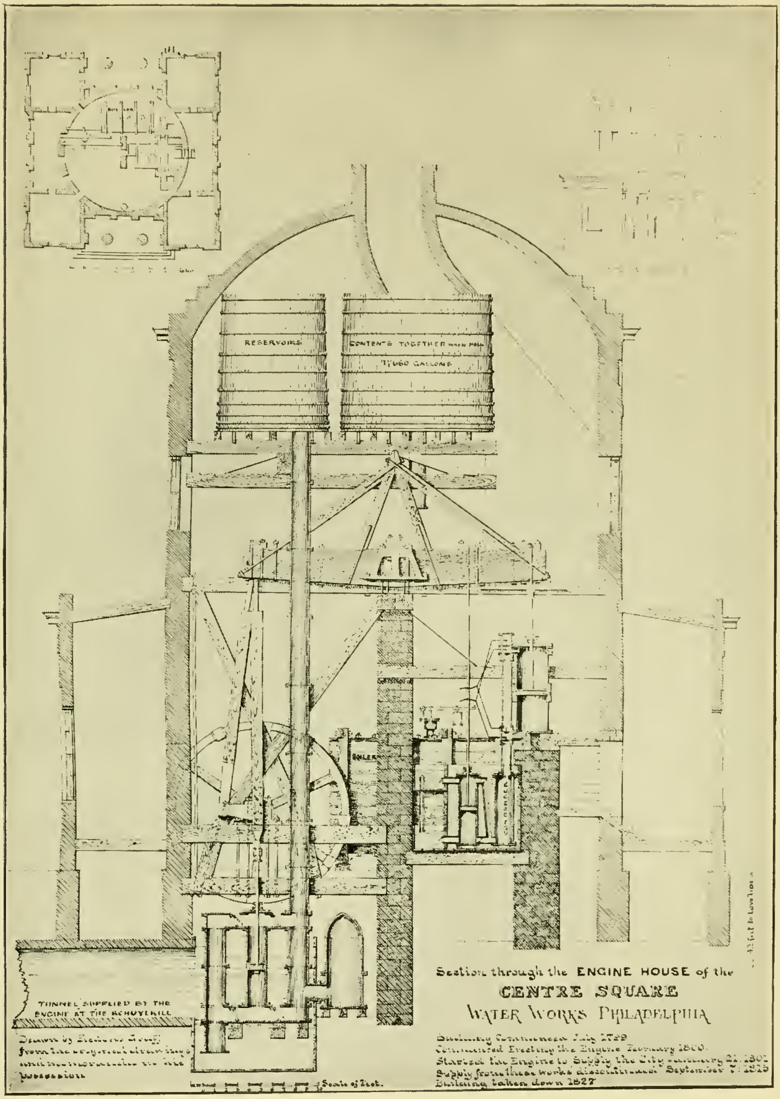


FIG. 2. CENTER SQUARE PUMPING STATION, PHILADELPHIA.
Built 1799–1801, on site of present City Hall, Broad and Market streets. Removed 1827.



CENTER SQUARE PUMP HOUSE, PHILADELPHIA. 1799–1801.
VERTICAL SECTION.

(The distortion of the two upper figures is due to unavoidable difficulties in photographing.)

cipal rods, beams, and shafts of the engines were also of wood, as were also the tanks, and, as we have seen, the distributing pipes. Some of the details of these boilers and engines are shown in Fig. 4.

The contractor for the engines was Nicholas I. Roosevelt, of Soho, N. J., a brother to President Roosevelt's grandfather. Nicholas, who afterward married Latrobe's daughter, was evidently a heavy loser through the contract, and the city suffered correspondingly, the "Watering Committee" finding it impossible to keep him up to time with his work. In particular, Mr. Roosevelt undertook to provide the Schuylkill engine with an "index" (probably a revolution counter). One annual report after another remarks that this "index" is not yet in place, and finally the mention of it is dropped. (See portrait, Plate IV.)

On the other hand, the city councils, then as now, found it possible to act the part of a thorn in the flesh of the engineer. Nicholas was practically bankrupted by delays in payments, and in one of his letters Latrobe writes, "First the sub-committee of the Watering Committee must assent to an agreement, then comes the Watering Committee itself, then the Common Council and the Select Council, — all avaricious, unjust, ignorant, and proud."

These first water works were completed and put in operation in 1801, but they gave most unsatisfactory service; and, the conditions having become intolerable, the old pumping stations and the conduit were abandoned in 1815, and the same distribution system was supplied by steam pumps (including one by Oliver Evans) at Fairmount, which pumped into a reservoir on the top of the rocky Fairmount hill. This reservoir, since greatly enlarged, but still one of the smaller reservoirs, and the old steam pump house, are still standing.

About 1820, a dam and breast wheels were constructed at Fairmount and the steam engines at that point abandoned.

The Fairmount works were constructed by Fred. Graff, Sr. (see portrait, Plate IV), who had been Latrobe's assistant from the beginning, and who was for many years in charge of the water works, as was his son, Fred. Graff, Jr., after him.

At the time of their completion, the Fairmount water works were one of the wonders of the world, and most of my contemporaries

Figures accompanying "First Report of Benjamin H. Latrobe, to the American Philosophical Society, held at Philadelphia; in answer to the enquiry of the Society of Rotterdam, 'Whether any, and what improvements have been made in the construction of Steam-engines in America.'"

American Philosophical Transactions
Vol. 6, pp. 89 &c

May 20, 1803.

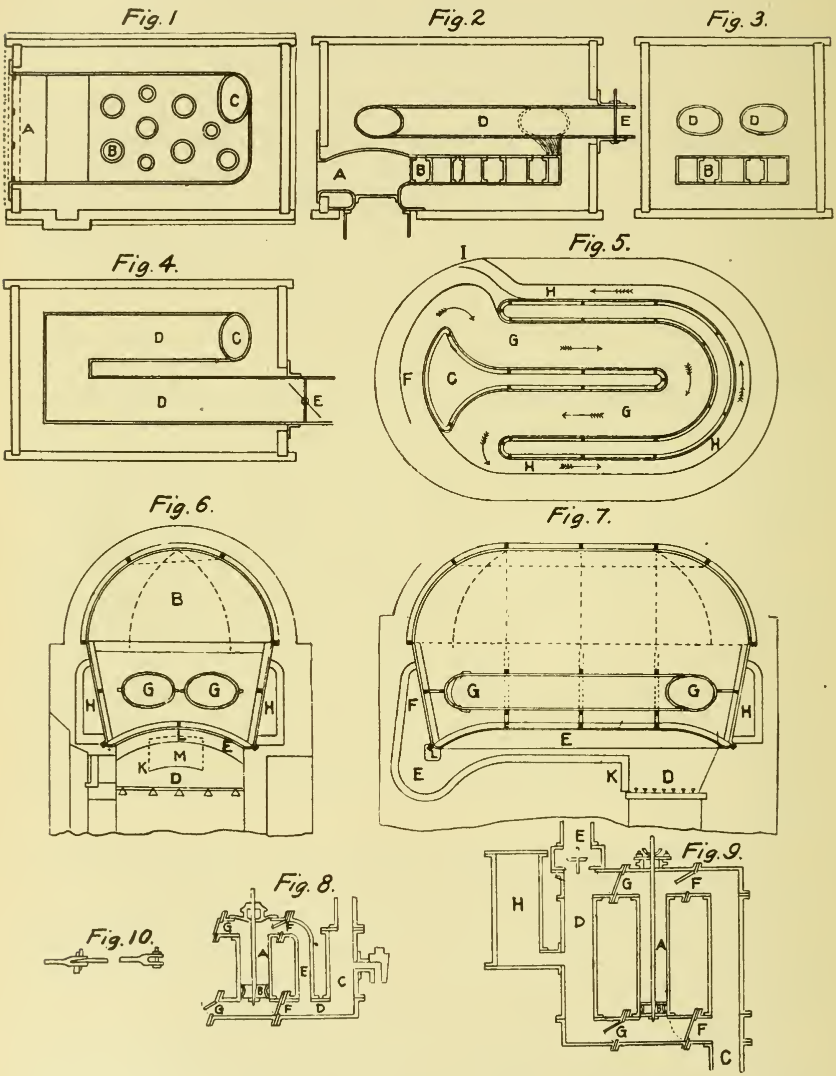


FIG. 4. BOILERS AND ENGINES, PHILADELPHIA'S FIRST WATER WORKS, 1799–1801.

(See opposite page for description of figures.)

will remember how they figured, along with Girard College, in the descriptions of Philadelphia in the school geographies, even as late as the fifties.

In 1851 the first turbine was constructed at Fairmount, and this remained the only turbine until 1867, between which and 1874 all the breast wheels were abandoned and succeeded by six new turbines, making seven in all. This Fairmount plant supplied the entire city proper between Vine and South streets, and, under contract, some portions of the adjacent districts.

In 1854 the city increased its area from 2 to 130 square miles (its present dimensions) by taking in the outlying "districts" and all the rest of Philadelphia County, making the city and county coterminous.

In the meantime, the adjacent districts of Kensington and Spring Garden had constructed steam pumping stations of their own, the Kensington works taking water from the Delaware, and the Spring Garden works from the Schuylkill. With consolidation, these works were taken over by the city, and thereafter the water supply system of the consolidated city grew rapidly.

RECENT CONDITIONS.

Prior to the inauguration of the present filtration system, that is to say, about ten years ago, the works consisted of six pumping stations, five on the Schuylkill and one on the Delaware, those on the Schuylkill being located on the east, or left, bank of the river, except the Belmont station, which supplied that portion of the city lying west of the river. About 90 per cent. of all the water pumped was then taken from the smaller stream, the Schuylkill.

DESCRIPTION OF SMALL FIGURES MAKING UP FIG. 4.

FIGS. 1, 2, 3, 4. Wooden Boilers.
- Fig. 1. Horizontal section through A B, Fig. 2.
- Fig. 2. Vertical longitudinal section at A, Fig. 1.
- Fig. 3. Vertical cross section at D, Fig. 2.
- Fig. 4. Horizontal section through D, Fig. 2.

FIGS. 5, 6, 7. Cast Iron Boilers.
- Fig. 5. Horizontal section through G, Fig. 7.
- Fig. 6. Vertical cross section through G, Fig. 7.
- Fig. 7. Vertical longitudinal section through B D, Fig. 6.

FIG. 8. Air Pump, double acting.
FIG. 9. Main Pump, water end, double acting.
FIG. 10. Braces for cast-iron boilers.

All of the stations, except the one at Fairmount, were operated by steam, and all pumped normally to open, elevated reservoirs, whence the water flowed, by gravity, into the distribution.

It frequently happened, however, that the pumps were unable to keep the reservoirs supplied against the enormous draft (due partly to the use of water, but much more largely to waste), and at such times it became necessary to cut off the reservoirs and to resort to direct pumpage. The dirty river water was then sent direct into our dwellings, without even the benefit of a day or two of sedimentation.

There were also three or four high-service stations, pumping to standpipes, and supplying small districts at elevations too high to be reached by the main pumping stations or supplied from the reservoirs.

The Roxborough station, that farthest up the Schuylkill, raised its water to an elevation of about 400 feet; the Fairmount, or lowest station, about 100 feet.

The Schuylkill river flows through prosperous agricultural and manufacturing districts, with numerous large and thriving manufacturing towns along its banks; so that, although cut off, by the Fairmount dam, from the major part of the city's own pollution, its waters had, long before the present filtration works were designed, become wholly unfit for household use, to say nothing of the fact that each flood in the river brought down, first, the new red shale mud from the districts near the city, and, a day or two later, the anthracite coal dust which had been stored in the navigation dams in the upper portion of the stream.

The Delaware, on the other hand, a larger stream, and flowing through a less densely populated district, was unprotected, by any dam, from the city's own pollution, which traveled upstream with every flood tide.

Notwithstanding this, no attempt at purification of the water had been made. The entire city was supplied with the same fluid which is now furnished to the central business and residence districts. With my apologies to those good people who hold that we should speak only good of our own town, I venture to assert that the conditions were ripe for improvement.

NICHOLAS I. ROOSEVELT, BROTHER OF PRESIDENT ROOSEVELT'S GRANDFATHER, AND BUILDER OF THE TWO STEAM PUMPING ENGINES OF PHILADELPHIA'S FIRST WATER WORKS.

FREDERICK GRAFF, ASSISTANT TO B. H. LATROBE, AND AFTERWARD CHIEF ENGINEER OF PHILADELPHIA WATER WORKS.

He designed and built the steam-power, and, later, the water-power works at Fairmount.

FIG. 1. FAIRMOUNT WATER WORKS, PHILADELPHIA.

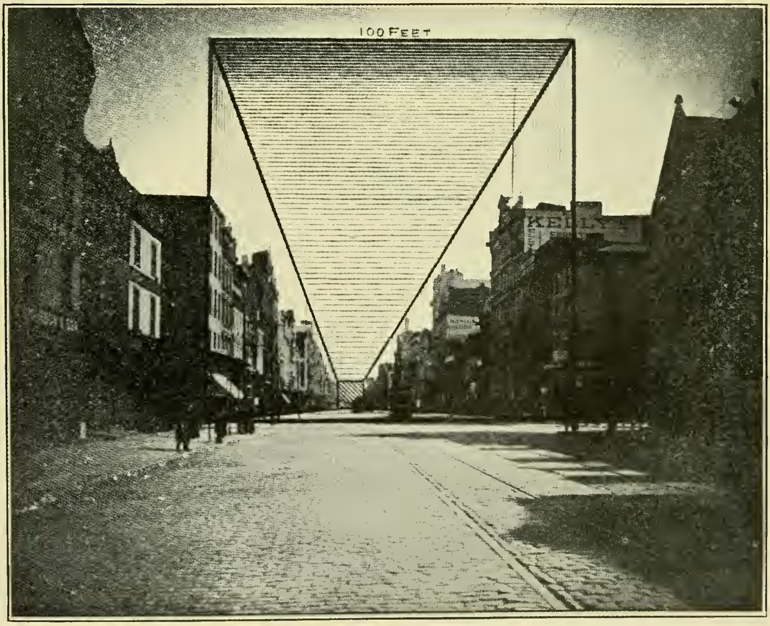


FIG. 2. 250 MILLION GALLONS.

(100 feet square, 3,300 feet long.)

MARKET STREET, LOOKING EAST FROM SEVENTH STREET TO DELAWARE RIVER.

Not only was the quality of the water atrocious, but the supply was ridiculously inadequate, and that solely because the people gloried in throwing away, unused, at least two thirds of all the water pumped.

With the greatest water-pumping plant on earth, running night and day, straining itself to the point of destruction, and pumping something like two hundred gallons per capita daily, a large portion of the city was constantly complaining (and with excellent cause) of the insufficiency of the supply, — the pressure, over much of the area, being insufficient to carry the water above the second floor; and all because one man in five was robbing the other four, and the four insisted that the robber should not be interfered with.

The average pumpage, deduced from plunger displacement and no doubt considerably exaggerated, was about 250,000 000 gallons per day. Even allowing for exaggeration, it probably approximated at least 200 000 000 gallons.

Market Street is one hundred feet wide between house-lines; and 250 000 000 gallons would fill Market Street, to a depth of one hundred feet, from the Delaware river to 7th Street, forming a square prism one hundred feet square and three thousand feet long, as shown on Plate V, Fig. 2.

During the agitation respecting the method of improvement of the water supply, a certain homeopathic physician, apparently well informed on many subjects, remarked, in one of his discourses in eulogy of the scheme in question, that " the people of Philadelphia would never submit to having their water doled out to them by the pint."

In order to show what ballast there was in this learned remark, I had three cubical frames prepared, covered with white muslin, and photographed. The largest of these frames was a 10-foot cube, containing, therefore, 1 000 cubic feet, which the city was then selling, by meter, for " thirty cents "; the next contained 1 000 gallons, or four cents' worth, while the smallest contained 1 000 pints, or one cent's worth. These 1 000 pints will furnish six comfortable baths.

In those degenerate days, our city fathers, and the statesmen who controlled the city's operations, were intent chiefly upon

obtaining and holding the control of things, and the sanitary condition of the city was a matter of quite secondary importance.

Although communities all about us were loudly proclaiming the benefits to be derived from the use of the water meter, our people were so densely and persistently ignorant of the matter that those who were most actively but unofficially interested in the improvement of the water supply, were ready to suppress abruptly any one who mentioned the water meter, and thereby threatened to arouse public opposition to the whole scheme of water improvement.

Under the circumstances, it is not strange that there was lively agitation for improvement. Commission after commission had studied the subject and made recommendations, most or all of which were ignored; and, as happened a hundred years before, all manner of rival schemes were actively advocated.

At this juncture, the writer found himself in charge of the Bureau of Water. He gave careful study to the subject of the improvement of the supply, both as to quantity and as to quality.

As to quantity, the result of course was that he persistently advocated the use of the water meter, and thereby not only alienated the politicians, who saw their welfare rather in the construction of unlimited pumps and "resavoys," but also lost the sympathy and coöperation of the public-spirited people who were forming themselves into associations for water improvement, and who were fearful lest all projects for improvement would be dashed by the mention of the ominous word "meter"; and this notwithstanding the fact that the city's finances at that time were (or were given out to be) such that the city could not possibly find means for the construction of works for the purification of the enormous quantities then used and wasted.

As to quality, the writer's studies had impressed him most forcibly with the facts (1) that filtration was the indicated solution of our problem; and (2) that the science of water purification was then in its infancy, that each supply must, to a great extent, be a law unto itself, and that each community must work out its own salvation with fear and trembling, and without relying slavishly upon the experiences of other communities.

He recognized, too, that the Philadelphia system lent itself admirably to just such experimental work as was required in its case, where the supply was taken from two rivers of quite different characteristics.

The single pumping plant on the Delaware was of moderate dimensions, as were two of those upon the Schuylkill, and he urged that the first step toward the filtration of the entire supply should be the construction of a filtration plant or plants in connection with one or two of these smaller stations, said plants to contain installations of each of the systems then best and most favorably known, in order that these might be tested in actual use and in competition with each other, and that the effects of filtration upon the public health might be tested in those limited districts.

It is needless to say that this scheme, like that for the restriction of waste, found no favor with the politicians in charge, and but little, if any, with the benevolent people who were agitating for improvement, and who insisted that the supply for the whole city must be purified at once. Experiment was taboo, for it meant postponement of completion, which, by the way, has not yet been brought about.

We were told that, if a beginning were made with one or two districts, all the others would be up in arms; yet that is exactly what has been done, and no revolution has resulted. We were asked whether filtration had not then "passed beyond the experimental stage."

Among the various schemes then claiming public attention was a large and well-assorted collection of water-snakes, in the shape of benevolent corporations, each with its champions in the city councils, and each kindly proposing to bring the impoverished city out of its water difficulties.

Notable among these was the Schuylkill Valley Water Company, which proposed filtering Schuylkill water, taken below Reading, and which was getting on swimmingly in councils, with every prospect of going through, when an inconsiderate member threw the fat in the fire by announcing that he had been offered a substantial sum for his vote in favor of the company's ordinance.

That such a trifle could block a scheme of this sort shows that the harmony, which has since reigned in the councils of the domi-

nant political party in our midst, had not then been completely established. Nowadays, any reptile cage placed before councils for approval, contains *but one* specimen, and every councilman knows what are his orders from "the front." In those days, however, the administration found itself opposed by an active and powerful faction, which ruled that all improvement of the water supply must await the inauguration of the succeeding administration which they hoped to, and which they eventually did, control.

The result of this policy is seen in the following comparison of estimates for extensions and improvements, and the corresponding appropriations, during the writer's term of service:

	Estimates.	Appropriations.
For 1896..........	$2,484 150	$0
,, 1897..........	3 339 450	0
,, 1898..........	3 735 050	0

Our boilers and engines were strained to the utmost, night and day, and in some cases disabled; there was no opportunity for thorough repairs; we dared not stop pumping during seasons of muddy water; in spite of all manner of pitiful expedients, we were compelled to cut reservoirs off from the distribution and resort to direct pumpage, in order to avoid emptying the reservoirs completely; and from all sides came loud and well-grounded complaints from citizens who paid for a water supply and did not get it.

Nevertheless, as we have seen, the Schuylkill Valley snake came within an ace of getting its appropriation of fifty millions.

During this time the city fathers passed a resolution providing that chiefs of bureaus should devote the whole (only the whole) of their time to the duties of their offices; and the practice of their honorable bodies seemed to be, when they became apprehensive lest the chief of the water bureau might not be earning his salary, to call for plans and estimates for the filtration of the city's supply. These plans and estimates were furnished, to the best of the bureau's abilities, which, at that time, were represented by an engineering force consisting of the chief draftsman and two or three subordinate draftsmen.

One of these requests for enlightenment mentioned "all the water used by the city," and the writer took advantage of the presence of the word "used" to lay before their honorable bodies

comparative estimates of the cost of filtering (1) all the water used, and (2) all the water used *and wasted*, with results as follows:

ESTIMATED COST OF IMPROVEMENT, 1898.

	For Water Used.	For Water Used. and Wasted.
Extensions........	$1 000 000	$5 000 000
Filtration plants . .	2 500 000	7 500 000
Meters............	1 000 000	0
	$4,500 000	$12 500 000

THE PRESENT TRANSFORMATION.

With the advent of the Ashbridge administration, in 1899, the scene shifted. A reassessment of real estate values was made, and the city was said to be in position to borrow practically any sums which might be needed for the improvement of the water supply.

Mayor Ashbridge called in an expert commission, consisting of Messrs. Rudolph Hering, of New York; Samuel M. Gray, of Providence, R. I.; and Joseph M. Wilson, of Philadelphia, who, according to the resolution providing for their appointment, were "to act in conjunction with the chiefs of the Bureaus of Survey and Water."

These gentlemen were, of course, given all needed assistance in their studies, and, after some summer months of hard work, including several all-night sessions by Mr. Hering, their report was published, recommending "the adoption of that project by which the waters of the Schuylkill and Delaware rivers, taken within the city limits, are purified by filtration."

In the body of their report the experts said, "We earnestly recommend the introduction of meters for the city of Philadelphia"; but in their résumé and conclusions the meter was not mentioned, and the deficiency in quantity of supply was ascribed to "the lack of effective pumping machinery and to the insufficient capacity of the distributing system."

The works have cost at least double what would have been required for a lavishly ample supply under proper regulation, and it costs correspondingly to operate them.

Mayor Ashbridge had expressed the wish that the works might

be such as to supply the city for fifty years to come, a view perhaps pardonable in a layman, who could hardly be expected to picture to himself what would be our plight to-day if *our* ancestors of fifty years ago (with the knowledge at their command) had constructed works sufficient for our present supply.

In brief, the report of the experts recommended the retention of all the existing Schuylkill pumping stations and of all but one or two of the smallest reservoirs, the adoption of rapid filtration at East Park reservoir, and of slow filtration for all the rest of the supply, the construction of a large slow-filtration plant and pumping station at Torresdale, and the abandonment of the Lardner's Point pumping station.

Plans were submitted, showing the proposed arrangements at each station and reservoir, and the relations of the several plants to each other and to the entire system.

Like the plan proposed by the experts, that now being carried out follows "that project by which the waters of the Schuylkill and Delaware rivers, taken within the city limits, are purified by filtration." In fact, the report of the experts may be said to form the basis upon which the plant is being constructed; but the two plans differ in certain important details.

The plan now being carried out involves in brief, the abandonment of the Fairmount pumping station, on the Schuylkill, and the construction of the great Delaware pumping station at Lardner's Point, instead of Torresdale; the old works at Lardner's Point to remain in service, this station being supplied with filtered water from the Torresdale filters by the celebrated Torresdale conduit, which formed no part of the plan recommended by the experts. Rapid filtration is discarded, and all the filters are of the covered slow type. The largest reservoir, East Park, will be used chiefly for emergency storage of raw water, and the largest of the old pumping stations, Spring Garden, which supplies East Park reservoir, will be held in reserve.

The long period of storage in the large upper Roxborough reservoir being deemed sufficient, preliminary filters are not used there. They are used, however, at Lower Roxborough and at Belmont, and they will be used at Queen Lane and at Torresdale.

The first preliminary filters, or "scrubbers," built in Philadel-

phia were those at Lower Roxborough reservoir. In them the water flows vertically upward, first through coke and then through sponge.

The next were those at Belmont for the West Philadelphia supply. In these the water flows first horizontally, through coke passing a 2.5-inch mesh; then horizontally again, through coke, passing a 1-inch mesh; then upward through sponge, and finally downward through coke breeze ranging in size from dust to $\frac{3}{8}$ inch.

Both of these plants were designed and built by Mr. P. A. Maignen, and both are working satisfactorily, materially reducing the load on the main filters and permitting a higher rate of filtration through them than would otherwise be compatible with safety.

At Torresdale and at Queen Lane the preliminary filters will consist simply of a series (120 at Torresdale) of rectangular "mechanical" filters, operated without coagulant, and cleansed by reversal of current, and jets of compressed air, as in the filter plants at Little Falls, N. J., and Harrisburg, Penn.

Apart from filtration, the prominent feature of the changes now being made is a reversal of the relation of the Delaware and the Schuylkill as sources of supply, the Delaware being now made the principal source, while the Schuylkill is to be altogether subordinate. Instead of 90 per cent., the new system will take only one third of its supply from the Schuylkill.

For Queen Lane, the experts proposed utilizing the north basin and the larger portion of the south basin for sedimentation, while the remainder of the south basin was to be converted into a clear-water reservoir, and slow filters were to be built upon ground lying just north of the reservoir.

Later, the administration proposed to remove the Queen Lane pumps to the Lardner's Point (Delaware) pumping station and to use the Queen Lane reservoir for the storage of filtered water from Torresdale.

Finally, however, it has been decided to retain the Queen Lane pumping station and to strengthen the foundations of the pumps, to use the entire south basin of the reservoir for sedimentation, and to construct preliminary and slow filters over the north basin, the filtered water to be collected in the lower part of the north

basin immediately under the filters. There will be no pumpage at the reservoir, the water passing by gravity first from the sedimentation basin to the scrubbers, then to the filters, then to the clear water basin, and finally to the distribution. The filters and scrubbers will be supported by concrete columns, piercing the

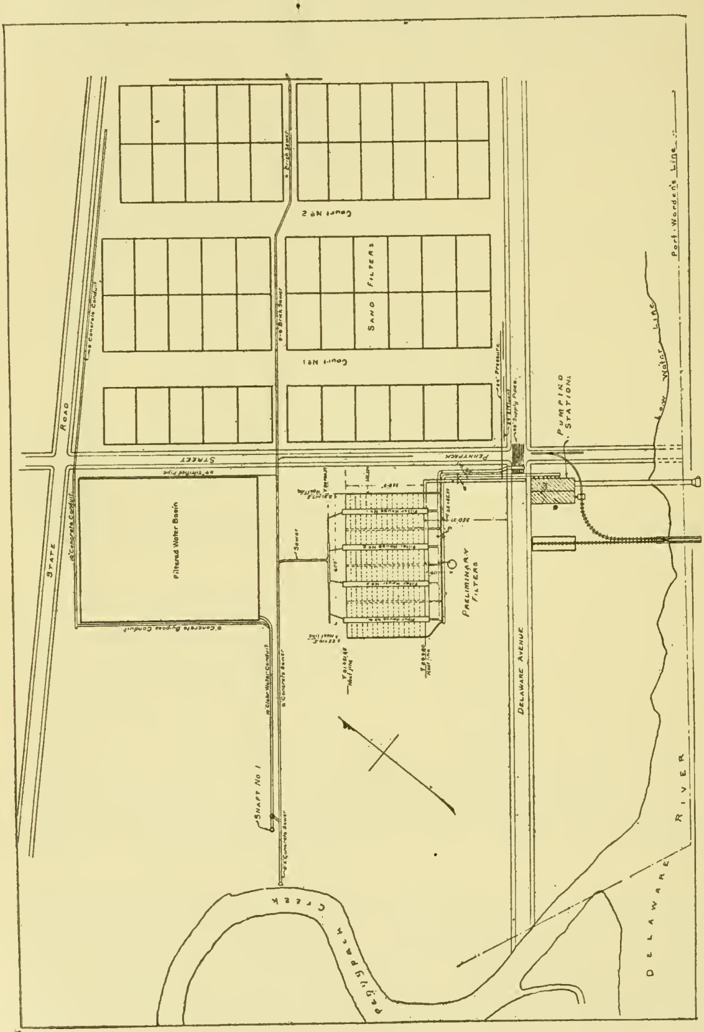


FIG. 5. PLAN OF TORRESDALE FILTER PLANT, SHOWING PUMPING STATION, PRELIMINARY FILTERS, 55 OF THE 65 SLOW FILTERS, FILTERED WATER BASIN, AND BEGINNING OF TORRESDALE CONDUIT.

concrete and clay puddle which form the present floor of the north basin, and resting on rock foundation.

On the Delaware, at Torresdale, two and one-half miles above the former intake at Lardner's Point, a slow filtration plant, believed to be the largest in the world, is now practically completed (see Fig. 5). Here the Delaware water is first lifted by centrifugal pumps to the filters, whence it flows to the adjoining clear water basin, and thence, through the Torresdale conduit, 10 feet 7 inches in diameter and 100 feet below the surface, to the Lardner's Point station, which has been enlarged to many times its old capacity, and which, under the new system, will form by far the largest station for the city's supply, and, it is believed, the largest high-duty pumping station in the world. The new portion of this station will contain twelve new twenty-million gallon pumping engines. When completed, the Torresdale plant will contain 65 filter beds, with a total filtering area of nearly 50 acres, and a preliminary filter plant of 120 rectangular mechanical filter tanks.

Practically, the supply from Lardner's Point will be by direct pumpage of filtered water.

The old Delaware works had but one reservoir, and that a small and defective one, and the great projected Delaware system has also but one small reservoir, and this acts merely to counterbalance the expected inequality between the day and the night demand.

Connected with the Delaware system is one high-service station constructed some ten years ago.

At the risk of advertising an old friend, I will mention that this Wentz Farm high-service station contains one of the few existing d'Auria pumps, another being in operation at the Pleasantville plant which supplies Atlantic City. These pumps are unique in their means for securing high-duty, viz., an oscillating or reciprocating body of water, which acts as a liquid balance-wheel, reversing its direction of motion at each stroke of the pump. The expensive crank and fly wheel are thus dispensed with. The Philadelphia d'Auria was purchased by the Water Bureau in an emergency, and it has since had a checkered career, having been moved about from one station to another and forced to operate generally under unfavorable conditions for which it was not designed. Some years ago it found a resting-place at this little Wentz Farm

station, where it ran for years without a condenser. This lack has been supplied, and Mr. Dunlap tells me that the pump is running well.

It may not be uninteresting to compare Mr. Hill's great Torresdale aqueduct of 1900 with Latrobe's Chestnut Street aqueduct

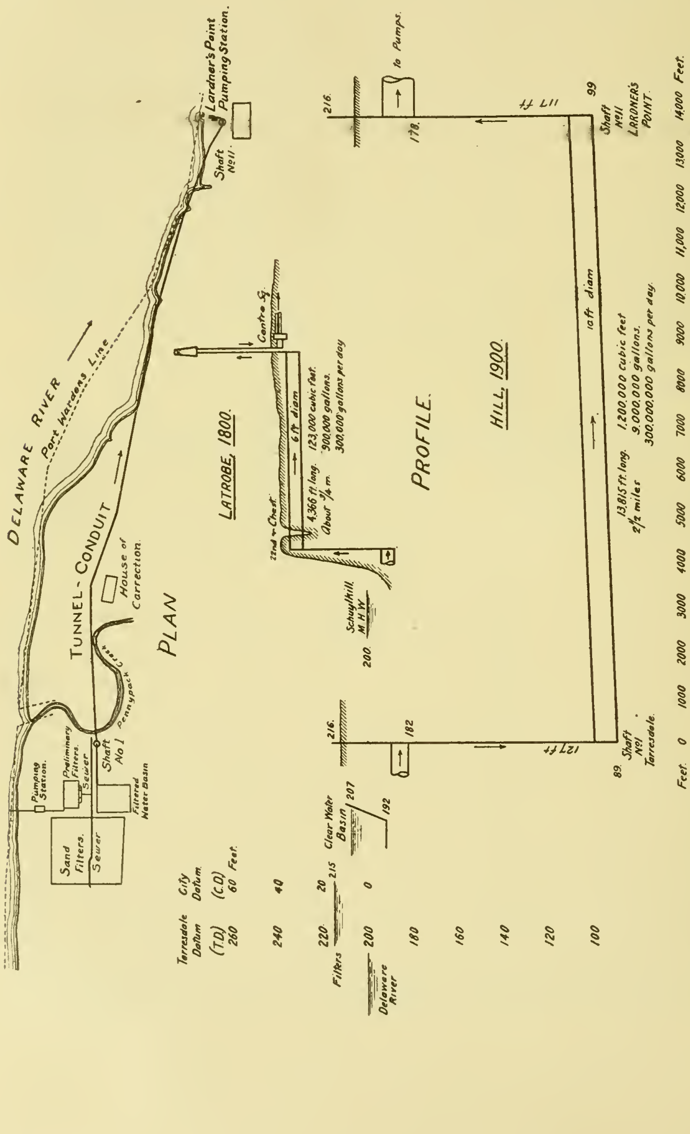


Fig. 6. Plan and Profile of Torresdale Tunnel Conduit of 1900, and Profile of Conduit of 1800.

of 1800. See the accompanying illustration, Fig. 6, which shows both structures at their relative elevations.

	Latrobe.	Hill.
Date	1800	1900
Diameter, feet	6	10
Length, feet	4 366	13 815
Contents, cubic feet	123 000	1 200 000
Capacity, gallons per day	300 000	300 000 000

For convenience of flushing, both aqueducts were given a gentle inclination downward toward their points of beginning. In the Latrobe aqueduct, the flow was by gravity; the slope of the water surface of course producing the flow, notwithstanding the slope of the aqueduct itself in the opposite direction. In Mr. Hill's tunnel, the flow is under pressure, and is caused by the difference in elevation of water surface in the shafts at its two ends.

In 1905 our quiet city was convulsed by a political upheaval. The politicians aroused popular resentment by undertaking a modification of the gas-works lease. Reformers, anxious for improvement, and would-be's, anxious for power and place, seized the opportunity. Mayor Weaver threw in his lot with the new party, threw out his Directors of Safety and of Public Works, and appointed Major Cassius E. Gillette chief of the Bureau of Filtration, to succeed Mr. John W. Hill. Major Gillette, in conjunction with Mr. J. Donald Maclennan, since deceased, reported that, in various ways, the city had been defrauded of some $6 000 000 by the contractors. Thereupon work was stopped for some time, but was afterward resumed, under Major Gillette's charge. With the advent of the present administration, Major Gillette was succeeded by the present chief, Mr. Fred C. Dunlap.

The average daily consumption, during 1907, based largely upon plunger displacement, was 300 000 000 gallons.

The total daily capacity of the works when completed may be stated as 340 000 000 gallons.

The Belmont plant, which supplies all of Philadelphia west of the Schuylkill, has a total nominal capacity of 40 000 000 gallons per day. It has been supplying all, or a part, of this district with filtered water since 1904.

The two Roxborough plants have a combined capacity of 25 000 000 gallons per day. They have been supplying their district with filtered water since 1903.

The Torresdale filter (as yet without scrubbers) in conjunction with the Lardner's Point pumping station (not yet completed) is already supplying the northeastern portion of the city, or say that portion east of Broad Street and north of Spring Garden Street.

The portion of the city not yet supplied with filtered water may be called the central and southern portion, or say the district east of Broad Street and south of Spring Garden Street, and that west of Broad Street and south of Allegheny Avenue.

The works are now filtering from 170 000 000 to 180 000 000 gallons daily. This is about half their intended final capacity and is more than an ample supply for nearly double our present population, but, as we are now wasting at least 100 gallons per capita per day, and using possibly from 50 to 70, I presume that only about one million persons, or about two thirds of our population, are at present supplied with filtered water, while the final supply, of 340 000 000 gallons daily, ample for 5 000 000 people, will be short rations for our one and a half millions.

The important works still to be completed are the preliminary filters at Torresdale, six high-duty pumps at Lardner's Point, and the Queen Lane filters. The preliminary filters at Torresdale are to be completed during the current year, and the Lardner's Point pumps early in 1909, or say ten years after the advent of the Ashbridge administration. The Queen Lane filters have not yet been advertised, and the date of their final completion must depend, to some extent, upon councilmanic appropriations, and these, in turn, of course, upon the grace of his reigning majesty, the Boss.

In round numbers, including engineering and incidental expenses, but exclusive of land damages and experimental and administrative expenses, the changes in the system since 1899, thus far completed or under contract, have cost 26 million dollars, and the work still proposed, but not yet under contract, is estimated to cost $2\frac{1}{4}$ million more, making a total of $28\frac{1}{4}$ million, of which 7 million are being expended upon the Schuylkill and $14\frac{1}{4}$ million

upon the Delaware, 5½ million upon distribution, and 1½ million upon repairs to pumps and stations.

As it will soon be nine years since the writer was officially connected with the Philadelphia water works, he need hardly say that, for most of the information here presented respecting the status and prospects of the works, he is indebted to the present chief of the Bureau of Water, Mr. Fred C. Dunlap, who has extended, to those taking part in this convention, an invitation to visit and inspect the works under his charge.

Any account of the water supply system of Philadelphia would be incomplete without mention of its high-pressure fire service, consisting of a pumping station, at foot of Race Street, Delaware River; four lines of mains, on Race, Arch, Market, and Walnut streets; connecting lines on Second, Fifth, Eighth, and Eleventh streets; and the requisite fire hydrants. Additional connecting lines are now being laid on others of the cross streets. The system extends from the Delaware River to Broad Street. All the mains are of flanged cast-iron pipe.

On Market Street the main is 16 inches in diameter; on Race, Arch, and Walnut streets, 12-inch; and on the cross streets, 8-inch. Chestnut Street was found already so encumbered by underground structures that no attempt was made to lay a fire main there.

The pumping station contains 9 pumps, 7 of 300 horse-power each, and 2 of 150 horse-power each, driven by a gas engine, supplied with gas from the mains of the United Gas Improvement Company.

The maximum fire pressure maintained is 300 pounds per square inch.

The system has been in service for about five years.

AN OLD AQUEDUCT AND ITS DEVELOPMENT.

BY ALBERT L. SAWYER, WATER REGISTRAR, HAVERHILL, MASS.

[*Read September 24, 1908.*]

The water-works system of Haverhill, Mass., is one of the ten oldest in point of organization in the entire area comprised in our Association. There is in our city hardly an institution or business existing to-day that at all approaches it in antiquity of origin, and it is and ever has been most intimately connected with the history and development of the city.

The first municipal water system of which we find record was established at Boston in 1652, consisting of a reservoir about twelve feet square, to which water from springs in the vicinity was conveyed through wooden pipes.

Of the 140 places in Massachusetts having water works in 1890, all but 9 had been built later than 1840, and for the most part since 1870. In the year 1800 there were but 16 places in the United States that had water works, and not one in Canada; and even as late as 1850 there were but 83.

As a matter of record, the sixteen built up to 1800 are enumerated as follows: Boston, 1652; Bethlehem, Penn., 1754; Providence, 1772; Geneva, N. Y., 1787; Salem, 1795; Plymouth, 1796; Hartford, 1797; Portsmouth, Worcester, and Albany, 1798; Peabody, New York City, Morristown, N. J.; Lynchburg, Va., and Winchester, Va., 1799; and Newark, N. J., 1800.

All of these, with the exception of Winchester and Morristown, were built by private companies, but passed into the control of the respective municipalities from time to time up to 1860. The aqueduct at Winchester was built by the municipality; that at Morristown is still owned by a private company.

Of course with a scattered population, where the houses had plenty of surrounding land, wells of pure water were able to amply supply the needs of the people. The denser growth of the towns, the introduction of sanitary plumbing, appendicitis, and the multitude of germs that make life miserable for us to-day, necessitated a corresponding development in the water supply.

It was perfectly natural that the citizens of old Haverhill should have been pioneers, for there are few places that have such an abundance of pure water on all sides, while the situation of the original village, clustered on the waterside, with a natural rise to the three great ponds, offered no problems requiring engineering skill; it was simply to provide an outlet and let the water flow downhill. In fact, we may well suppose that the existence of these natural reservoirs had much influence with the first settlers in the choice of a location for their homes; and certainly there could have been few locations with a more abundant supply of water.

The town of Haverhill, or, as it was originally called, Pentucket, was settled in 1640 by a band of twelve men from Newbury and Ipswich, joined soon after by Rev. John Ward, who became the leader of the settlement, and whose original house is still standing and in the care of the Historical Society. I have a facsimile of the deed from the Indians, Passaqua and Saggahew, in which they made a grant of the lands for the sum of three pounds and ten shillings. As first laid out the town was nearly in the form of a triangle, and included a large portion of the territory now forming the towns of Salem, Atkinson, Hampstead, and Plaistow in New Hampshire, and Methuen in Massachusetts. From the river side the land gradually rises till we come to the large ponds. The nearest, and also the smallest, was Plug Pond, now Lake Saltonstall, and formerly called Ayers Pond from the fact that several people of that name settled near its western end and owned a large part of the adjoining land. This pond has an elevation of 122 feet and covers 70 acres. At the southern extremity was a dam called the "plug dam" in one of the old documents, from which, doubtless, the name of the pond.

Next came Round Pond, with an elevation of 152 feet and containing 80 acres. Round Pond is remarkable from the fact that not a single stream, even of the smallest kind, flows into it, it being supplied, with the exception of the flowage from the surrounding hills, by subterranean springs. Except at one place at the northwest corner, it has a clear, sandy bottom. The natural outlet was toward the southwest into Little River, but the direction of this outlet was long ago artificially changed to secure the surplus water for the mills on the mill brook.

Kenoza Lake, formerly known as Great Pond, was the largest, covering 225 acres, at an elevation of 110 feet, with a large watershed and surrounded by beautifully wooded hills. Its outlet was Fishing River. In 1859 a number of the leading citizens formed a club, purchasing a lot of land on the shore of the lake to be used for picnics and social gatherings.

To John G. Whittier was intrusted the honor of selecting a new name for the pond, and the result was his beautiful poem, "Kenoza," in which he refers to the change of name and to the rare beauty of its natural setting.

> "Lake of the pickerel! let no more
> The echoes answer back 'Great Pond,'
> But sweet Kenoza, from thy shore
> And watching hills beyond.
>
> "Kenoza! o'er no sweeter lake
> Shall morning break or noon cloud sail;
> No fairer form than thine shall take
> The sunset's golden veil."

Crystal Lake, formerly called Creek Pond, was situated about three miles away to the west, and covers 159 acres, with an elevation of 152½ feet. Its shores, quite irregular, are beautiful in spots, the water remarkably clear and transparent, and the bottom for the most part even and sandy. Its outlet is Creek Brook, emptying into the Merrimac.

It was not, however, until about 1799 that any steps were taken to bring the water by gravity to the cluster of houses on the banks of the river, in the fork of the roads formed by the intersection of Main and Water streets. Mr. David How, who at the commencement of the last century was one of the leading citizens of the town, was the first to enter on the project of laying a pipe to bring water from Round Pond to his farmhouse. Iron and even clay pipes were then unknown in this country, and the only method for the conveyance of water was by the use of wooden conductors or bored logs. Mr. How's farmhouse was directly back of that portion of our main thoroughfare now occupied by retail business houses. Here, directly in the center of the town, was his house, and around it were clustered his cow yard and pigpens. There

are some old residents who remember the house as it stood in 1835. Mr. How was still living, but old and infirm. His establishment was then regarded as a nuisance; the dilapidated buildings were reeking with filth, and the stench from his pigpens was an annoyance to all in the little village. To this place Mr. How was desirous of bringing water, and with the assistance of neighbors, green pine logs were bored with a two-inch auger, and a line of pipe was laid to Round Pond.

The idea of an aqueduct appears to have appealed to others of the townspeople, and in 1798 the following petition was presented to the legislature then in session in Boston:

To the Honorable the Senate & House of Representatives of the Commonwealth of Massachusetts in General Court Assembled.

The petition of Timothy Osgood of Haverhill in the County of Essex & Commonwealth aforesaid in behalf of himself & others Humbly Shews they have in contemplation sinking an aqueduct taking the water at & from the round pond so called in Haverhill & conveying it through the several streets of said Haverhill for the use & convenience of themselves and others who may be desirous of becoming concerned therein & for their greater convenience & security they pray your Honors would grant to them & such others as my associate with them an act of Incorporation Impowering them by the name of Haverhill Aqueduct Company to convey water into the streets in said Town through aqueducts with all such powers rights & privalidges as the subject matter may render necessary & as in Duty bound will ever pray.

Timothy Osgood *in behalf of himself & others.*

Haverhill Jan[y] 8th, 1798.

There were, however, some who did not favor the innovation, for we find in the records of the same year that the town's representative, Mr. Nathaniel Marsh, was instructed "to oppose Osgood's petition for an aqueduct to take water from Round Pond." The petition was evidently granted, however, and in 1801 we find in the town records the steps taken for the formation of the company which from that time on furnished the water supply of the town. This petition was referred to a committee, of which Bailey Bartlett, who for several years was sheriff of the county, was chairman,

who reported that leave ought to be granted provided that a book for the subscription to the stock was opened to all who chose to take a share; that no one should be allowed to take more than one share until ninety days after the book was opened, at the end of which time the remaining shares might be taken by any of the subscribers; and that the rules of the company be offered to the town for approbation. The following is a copy of the advertisement inviting subscriptions to the stock of the new company.

AQUEDUCT COMPANY.

Notice is hereby given, a subscription
open at the store of Benja. Willis Jun.
for Subscribers to the Aqueduct Company,
which will be kept open for ninety days
agreeable to a vote of the Town, for
any person who may wish to become
a proprietor.
HAVERHILL June 10, 1802.

We might wonder why it was that the first water was taken from Round Pond instead of going to Lake Saltonstall or Plug Pond, which were so much nearer. At that time the outlet of Plug Pond was the mill stream that came down the valley between the old cemetery and the road, entering the Merrimac at the foot of Mill Street, and known as Mill Brook. This brook was about one third of a mile long and had a fall of one hundred and twenty-two feet in that distance, which, with the dam before mentioned, gave ample water power. On this stream was situated the first gristmill of the early settlement. Along the stream at the date of the incorporation of the aqueduct were several manufactories, a tannery, a bark mill, a hat factory, a sawmill, a gristmill, and, at a somewhat later date, a woolen mill; and of course the drawing down of the pond to any great extent would affect the water rights of these mills. In fact, in 1815 a suit was entered against the aqueduct company because they were taking water from Round Pond.

In 1814 Leonard White had conveyed land on the brook and the mill privilege connected with the same to the Haverhill Cotton and Wool Manufactory. A mill was started and cloth manufactured. The next year the company, in the name and with the assent of Leonard White, brought action in which they set forth that by

supplying the inhabitants of Haverhill with water from Round Pond the company unlawfully diverted the waters which were a part of Plug Pond and to which the owners of this land and mill privilege were entitled. The manufacturing company was awarded judgment, and from that time until 1849 the aqueduct company used the waters of Round Pond, under an agreement whereby they paid the owners of the land compensation for doing it. Later the company purchased all the land between Plug Pond and the Merrimac River, paying sums ranging from $200 to, in a single instance, $10 000. The Leonard White referred to above was the first treasurer of the aqueduct company, and was placed in the position of bringing suit against his own company on account of having sold the land to the woolen mill.

Having received their charter, the parties interested soon took steps to organize the company, and on October 11, 1802, met at Harrod's Tavern, which stood on the site of our present city hall. I have here the records of that first meeting; this and the records and accounts for many years being in the clear, legible writing of Mr. Leonard White, the clerk, who was, I believe, later the first cashier of the Merrimack National Bank at its incorporation in 1814. (Plate I.)

I ought, as a careful historian, to call your attention to the fact that if they did not at once begin to water the stock, they did at this first meeting mix rum with their water, to the success of the new company, in the good old West India variety, and here is the bill of Landlord Harrod covering the same. (Plate II, Fig. 1.) And I regret to say that this is not all of the sad tale, for as the company got under way their thirst increased in quantity and quality. Let me give you another sample. (Plate II, Fig. 2.)

The managing directors of the company were Hon. Bailey Bartlett, Benjamin Willis, and James Duncan, Jr., and in looking over the records of these early days I have been impressed by the very businesslike way in which all was done. Although the town was small and these men must have seen each other daily, every order to the treasurer for the payment of money is in the writing of the directors; and Mr. Harrod, who was one of the incorporators, never forgot to put in his bill for liquor consumed. When James Duncan went to Boston and brought out the iron for binding the logs, we

find his bill for thirty-five cents, and there is a bill from Bailey Bartlett of thirteen cents for a paper book and other items, concluding with a charge of forty dollars for overseeing the laying of the logs. They all appear to have cheerfully paid out of one pocket assessment after assessment on their stock, and then as cheerfully got the most of it back into the other pocket in the shape of bills and sundry small dividends declared from time to time.

We have heard considerable at some of our meetings about specifications for iron pipe, and you may some of you like to hear the original contract and specification for pipe made in 1803:

Articles of Contract and agreement made this 26th. day of Jan. 1803 Between Bailey Bartlett, Benj. A. Willis and James Duncan Jr. in behalf of Haverhill Aqueduct company on the one part and Enoch Noys of Barr in New Hampshire on the other part witnesseth

The said Enoch Noys for the consideration hereafter expressed does hereby contract and engage to deliver at some landing near Haverhill Bridge on or before the 20th day of May next, eight thousand feet in length of good sound white or yellow pine timber of the following dimentions; no stick to be less than fifteen feet in length; one third of the quantity to measure at the top end nine inches; one third ten inches, and one third twelve inches, the same to be straight and sound and said measure is to include the heart only.

And the said Bartlett, Willis and Duncan in behalf of said proprietors do hereby engage to pay said Noys at the rate of twenty shillings for each and every ton the same shall measure, reconing the same as measured at the top end and free from sap and of the three several dimentions as above stated, the same to be paid on delivery of the whole timber.

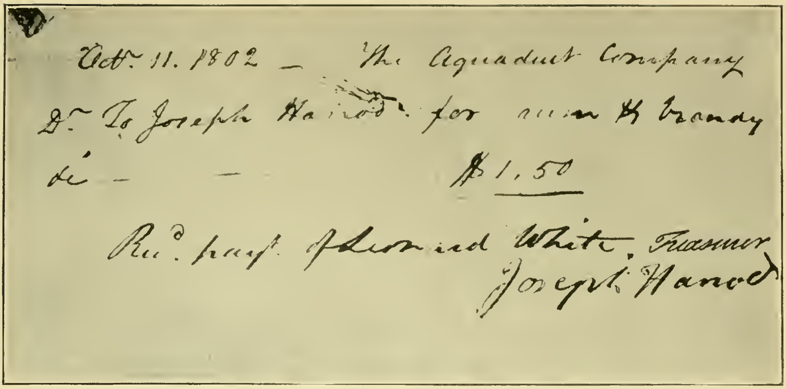
Bailey Bartlett
Signed in the presence of Benj. Willis
Robert McGregor Enoch Noyes

Contracts to be made for the Aqueduct Company in Haverhill.

1803

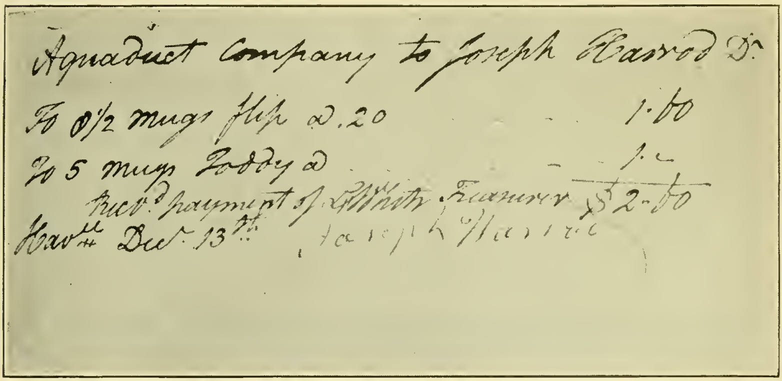
May 3. First for Digging the Ditch to lay the Logs from a Stake & Stones near the Pond Brook to a Stake & Stones

No. 1 by Sam Walkers land about 150 Rods — the ditch to be not less than $3\frac{1}{2}$ feet Deep and wide enough to lay the logs, the bottom of the Ditch to be level, sufficient for the logs to lay fair on the same.



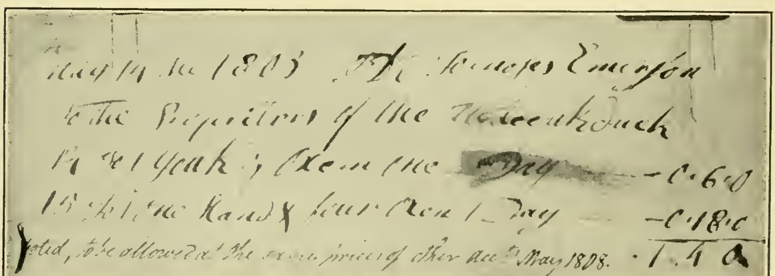
Octr. 11. 1802 — The Aqueduct Company
Dr. To Joseph Harrod for rum & brandy
&c — — $1,50
Recd. payt. of Leonard White Treasurer
Joseph Harrod

FIG. 1. FIRST BILL PAID BY THE AQUEDUCT COMPANY.



Aqueduct Company to Joseph Harrod Dr.
To 8/2 mugs flip @ .20 — 1·60
To 5 mugs Toddy @ — 1.—
Recd. payment of L. White Treasurer $2-60
Havll. Decr. 13th. Joseph Harrod

FIG. 2. ANOTHER EARLY BILL.



May 14th 1805 Mr. Thomas Emerson
to the Proprietors of the Haverhill Aqueduct
To 1 yoke Oxen one Day — 0.6.0
To hire of Hand & four Oxen 1 Day — 0.18.0
Voted, to be allowed at the same price of other accts. May 1808. 1.4.0

FIG. 3. BILL FOR HAULING LOGS.

No. 2 Contract — beginning at the lower End of N°. 1 — and continue to Caleb Bosquets House opposite the Front Door.

No. 3 From the above mentioned Door to Hav'll Bridge.

N. B. In case, the Contractors in digging any part of the ditch abovementioned, should come across any Rocks of more than ten hundred Weight or Fast ledge of Rocks they shall have liberty to dig round the same, or to remove the rocks at the direction of the Directors, in which case the Directors will pay the extra expense. Where it is necessary to take down any walls in the prosecution of the work, they shall be put up by the directors at the expense of the aqueduct Company.

No. 4 Contract for covering the Logs when laid; the whole dirt taken out, to be thrown upon the Logs as fast as they are laid, and ready for covering. From the Pond to the Bridge the same to be by the Rod.

No. 5 Boring Fixing & laying the logs Fit for Covering, the Proprietors to find the Iron Hoops to put on the ends of the logs. 4000 feet of Logs with a two Inch Augur
4000 feet Do $1\frac{1}{2}$ Inch bore — to be well rimmed out. the whole to be done in a workman like Manner and to the approbation of the directors and to Include the logs to extend from the main logs to the Houses

The contractor evidently had good luck, for here is the bill of Moses Emerson, dated May 14, 1803 (Plate II, Fig. 3), against what he terms the " Accuduck " for the use of oxen in hauling the logs from the landing. But I must stop no longer with these interesting relics of the past.

Returning again to the log aqueduct, let me refer to some of the early trials and tribulations that even to the present day are connected with water-works administration. After the water had been let on, the pressure was so great that the log pipes, unable to stand the strain, burst. This was a grave difficulty, and all the hydraulic skill of the times was brought to bear on the problem. At last the idea was hit upon of making a break in the pipes half way down the hill, by digging a pit, and thus relieving the pressure. This pit was placed nearly opposite the Unitarian Church and remained there for nearly forty years.

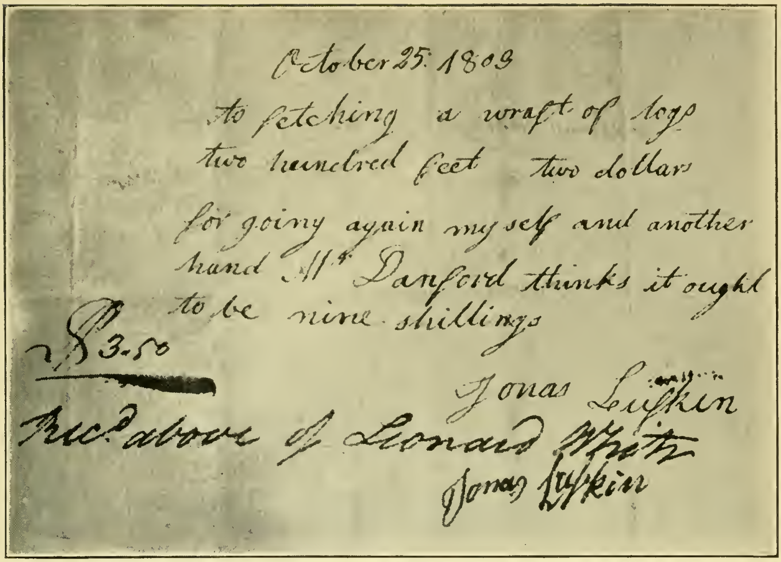
In the early stages of the company no water was carried above

the first story of the houses, and no lead or metal stop cocks were in use. The logs were brought directly into the kitchens and cow yards, and an upright bored log with wooden faucet held the water for use. A curious device was used on Main Street, near the North Church, to elevate the flowing water so as to bring it into the kitchens of the houses. It was found that the water would flow through the logs all right, but it would not stop to be taken on the way; and to remedy this evil, an upright log was interposed and bored double, so that the water was forced to ascend one tube to the top and flow over for its passage down town. This held the water back so that customers on the level street could get a supply. This was considered a great piece of engineering skill, and some elderly citizens might doubtless recall how as boys they jumped on the log and listened to the murmur of the water as it flowed over.

It has been said that various evils result from indulgence in strong drink, and in the case of the aqueduct company it took the form of — betting! The hydraulics of the working plant of the company caused differences of opinion as to pressure, etc., and at last, doubtless after a business meeting held by the open fire at the hospitable Harrod's, the discussion grew heated, there was a division among them, and the following bet was made:

> The bet is in the form following, viz.: a barrel being filled with water and set on the ground a tube of ½ inch bore & 40 feet long inserted into the barrel & made tight, and filled with water and a funnel on the top of the tube filled also with water, the barrel will burst.

Burst.	Will not Burst.
B. Bartlett	J. Duncan
D. How	B. Willis, Jr.
L. White	M. Atwood
O. Tucker	P. Osgood
M. Brickett	B. Willis
C. Kimball	N. Ayer
J. Harrod	D. Brickett
T. Jordan	D. Portor Jun.
T. Brickett	H. West
N. Marsh	
E. Hale	



October 25 1809

To fetching a wraft of logs two hundred feet two dollars

for going again myself and another hand Mr Danford thinks it ought to be nine shillings

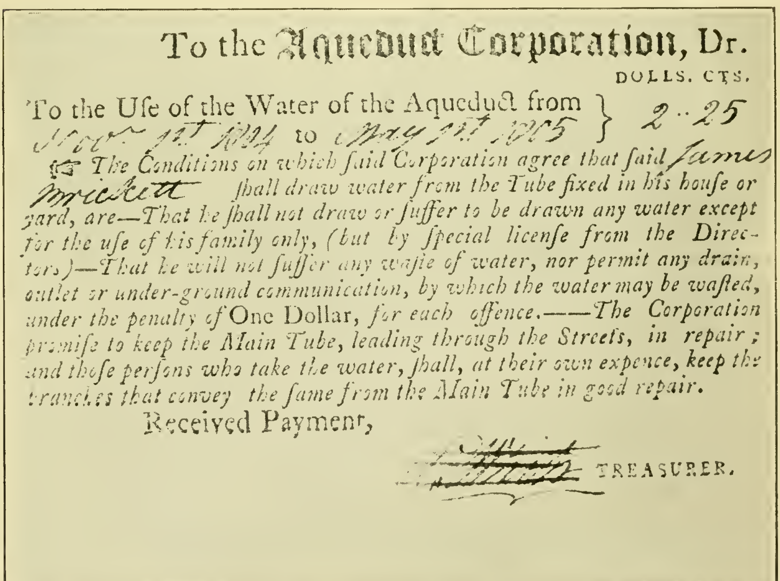
$3.50

Jonas Lufkin

Recd above of Leonard White

Jonas Lufkin

FIG. 1. BILL FOR RAFTING LOGS FOR PIPE.



To the Aqueduct Corporation, Dr.

DOLLS. CTS.

To the Uſe of the Water of the Aqueduct from Nov. 1st 1804 to May 1st 1805 } 2 . 25

☞ The Conditions on which ſaid Corporation agree that ſaid James Mrickett ſhall draw water from the Tube fixed in his houſe or yard, are—That he ſhall not draw or ſuffer to be drawn any water except for the uſe of his family only, (but by ſpecial licenſe from the Directors)—That he will not ſuffer any waſte of water, nor permit any drain, outlet or under-ground communication, by which the water may be waſted, under the penalty of One Dollar, for each offence.——The Corporation promiſe to keep the Main Tube, leading through the Streets, in repair; and thoſe perſons who take the water, ſhall, at their own expence, keep the branches that convey the ſame from the Main Tube in good repair.

Received Payment,

TREASURER.

FIG. 2. AN EARLY BILL FOR WATER RATES.

As the town grew, the two-inch logs were found insufficient to supply water, and about 1830 four-inch logs were substituted, and the aqueduct was extended to some of the streets intersecting with Main Street. The price at first charged was $4.50 for houses and beasts, providing subscription for taking the water was made before the logs were laid, otherwise it was to be $5, and an additional charge was made for each additional post. There appears to have been no printed rate sheet until 1822. In making this the proprietors evidently took as a basis the rules and rates of the Salem and Danvers aqueduct as established in 1797, which I have altered in several places, and marked " adopted by the Haverhill Company." The rules as finally adopted and printed were as follows:

RULES AND REGULATIONS of the
HAVERHILL AQUEDUCT COMPANY, AS AGREED
ON BY THE PROPRIETORS, JUNE 14, 1822.

Article 1. — The Proprietors engage to support the expence of maintaining the main tube from the Pond, and ten feet offset from the same, measuring from the centre of the street; the remainder of the branch and vent-stock shall be made and supported by the person who takes the water, under the care and direction of the Agent of the proprietors, or of one of the directors.

Article 2. — The Annual sum to be paid for the use of the water from said Aqueduct, shall be as follows . . . viz.
For all families less than nine persons in a family,
Eight Dollars.
For all private families of nine persons, or more,
Nine Dollars.
For a Tavern or public Boarding house,
Eleven Dollars.
And if for a House and Stable, Fifteen Dollars.
One half to be paid to the Treasurer in Six months, and the remainder in Twelve months from the time of taking the water.

Article 3. — The Annual sum to be paid by Distilleries, Manufactories, or other persons not included in the above, shall be such a sum, and under such regulations as may be agreed on with the Directors, to be paid in the times above specified.

Article 4. — No person taking the water from said Aqueduct, shall suffer a waste of water, or permit any person other than his own family to take the same.

Article 5. — Every person having a branch shall be subject to have the drawing place therefrom, and everything appertaining thereto, inspected at the direction of the Agent, or one of the Directors, whose duty it shall be to superintend the works generally.

Article 6. — Should there be a deficiency of water, on notice thereof being given to the Agent or one of the Directors, the pay for such time shall cease, if occasioned by a want of water in the main tube; but the proprietors will in no case be responsible for defects in the offsets or ventstocks, arising from frost or other causes.

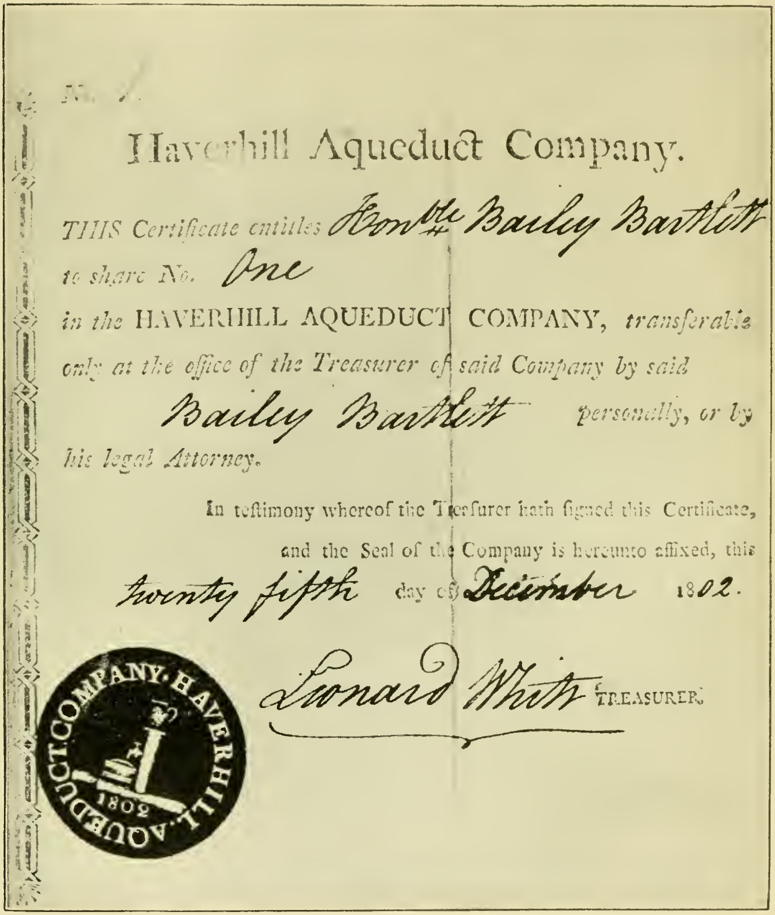
Article 7. — In order to prevent freezing, all persons taking water for family use will have liberty (at their own expence) to take it into their cellars, as well as above stairs.

Article 8. — Each person taking the water from said company, shall be furnished with a printed copy of these rules subscribed by the Clerk, and shall also subscribe a like copy to be kept by the Clerk of said company, stating that they will conform to these regulations and also stating the number of persons in his family and the use he expects to make of the water.

CHARLES WHITE, Clerk to Props.

The prices for water varied somewhat until 1845, when a uniform tariff was made for ordinary family use, and the rates were not materially changed thereafter until the works were taken over by the city.

An old man by the name of Jordan had sole charge of the works, and the boys were in the habit of calling the aqueduct the "River Jordan." He bored the logs, put them down, attached faucets, made repairs, thawed out the stream when it was frozen, made out the bills, and collected the money as well as he could. He was the one who "ran the machine." His services were in constant demand, especially on frosty mornings, and old boys have told the story of being called out in the cold gray of the morning to hunt up "old Jordan" to thaw out the frozen logs. His house was at



No. 1.

Haverhill Aqueduct Company.

THIS Certificate entitles Hon^ble Bailey Bartlett *to share No.* One *in the* HAVERHILL AQUEDUCT COMPANY, *transferable only at the office of the Treasurer of said Company by said* Bailey Bartlett *personally, or by his legal Attorney.*

In testimony whereof the Treasurer hath signed this Certificate, and the Seal of the Company is hereunto affixed, this twenty fifth day of December 1802.

Leonard White TREASURER.

HAVERHILL AQUEDUCT COMPANY 1802

FIRST STOCK CERTIFICATE ISSUED BY HAVERHILL AQUEDUCT COMPANY.

the corner of Main and Pond streets, and an elderly gentleman told me within a year that he well remembered the piles of logs stored by the roadside, and watching the boring process carried on. I have two samples of the log aqueduct (Plate V). This large section is undoubtedly a piece of one of the very early logs laid, as it was dug up at the corner of Main and Water streets. The other section is of a much later vintage, being dug up on Kenoza Avenue. You will note the marks where it was strengthened by hoops of iron.

About 1840 the old aqueduct was found to be inadequate to supply water, and Charles Minot, Esq., a well-known lawyer, took it in hand, raised money, and extended the pipes. The number of shares was one hundred and the par value, I believe, was $25. With the funds obtained he laid some iron pipe and put the works in better repair. After a few years Mr. Minot was called to act as superintendent of the Boston & Maine Railroad and the aqueduct was purchased to a large extent by Hazen Haseltine, an active business man of the times. His business career was, however, terminated by a failure, and among his assets was a majority of the stock of the company, which passed into the hands of his brother, Ward B. Haseltine, of Philadelphia, who took it, much against his inclination, as security for money loaned to his brother.

Soon after 1845 it was found that more water was needed, and Plug Pond was tapped. Quite a controversy took place at this time over the so-called encroachment of a soulless corporation in planning to take water from this pond, and so destroy forever the beauty and utility of the old mill brook. The culminating point was perhaps reached in the following communication, published in the *Tri-Weekly* by one who signed himself " Mill Street ":

" More beautiful to my youthful eyes were the buttercups and thistles which grew on the borders of this much-talked-of brook than the rarest exotics in the parterres of the wealthy and great. The fairy-like music of its crystal waters, as they roared and rippled and seethed and surged and tumbled over its stony bed, was ever suggestive of elves and water-nymphs.

> ' I envied the brook as it glided along,
> Thro' its beautiful banks in a trance of song.'

But there is one point your correspondent has failed to notice,

which would, 'I apprehend,' be more regretted by lovers of art than words could express. I refer to the sweet and pathetic music of the frogs. Have you ever, Messrs. Editors, on a calm, moonlight midsummer's eve, seated yourself on the grassy bank of the upper Mill Pond and drank in the beauty and inspiration of the scene? the majestic rock-ribbed hills in the distance, the stately poplars, the regal sycamores, and the graceful elm reflecting every limb, and twig, and leaf, in the glassy mirror below; the whole scene, so tranquil and soothing, undisturbed by any earth-born sound, save the dulcet melodies of the frogs. The deep diapason of the masculines, the soft, tender responses of the lady frogs, the sweet baby trills of the pollywogs, and the blending of the three in one harmonious whole, produce such a 'concord of sweet sounds' as to make one feel in his heart of hearts the sentiments of the immortal poet, 'linked sweetness long drawn out.'

"I, in company with appreciative friends, have often listened in charmed ecstacy, and the memory of such evenings is 'a joy forever.' And are we, and our children, and our children's children, to be deprived of this exquisite source of enjoyment, so refining and exalting in its nature, for the accommodation of a 'few individuals' who, under the pretence of 'supplying the town with pure water,' are committing acts of vandalism on Mill Street that *no* necessity ought to justify?

"MILL STREET."

Again, in 1867, the two sources of supply proved inadequate, and the owners went to the legislature for permission to draw water from Kenoza Lake. An act was passed, with certain restrictions:

1. Private property was safeguarded by preventing the raising of the ponds *above* high-water mark or lowering them below low-water mark.

2. The water of none of the ponds could be used to drive machinery.

3. A plan was provided by which the city could take over the works.

In 1848, at the town meeting, a proposition was made for the town to pay the difference between a 5-inch and 8-inch iron pipe from Round Pond to the top of the hill on Main Street, the Aqueduct Company being about to replace the old logs with a 5-inch pipe of iron. A committee to whom it was referred reported in favor of a 6-inch pipe, which was laid, the town paying the difference in cost. Soon after this Mr. James H. Carleton obtained

FIG. 1. PIECE OF LOG PIPE.

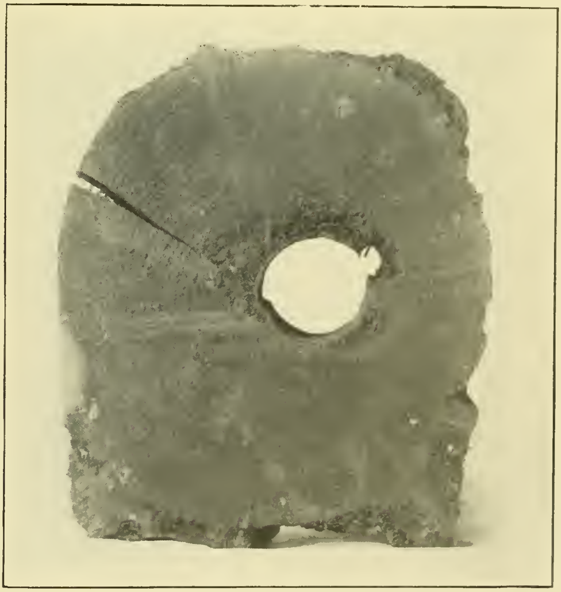


FIG. 2. SECTION OF LOG PIPE.

control of a number of shares held by various local people. For more than forty years the stock was owned by the two previously-named gentlemen, the rest being divided up among five prominent citizens. Mr. Carleton was for many years treasurer and superintendent, being succeeded later as superintendent by Mr. Charles W. Morse, who continued until the city took possession in 1891.

In 1871 a small pump was erected at Kenoza Lake and water was pumped into Round Pond, the system still being gravity. In 1879 the growth of the city had extended greatly and buildings were being erected on the high lands of the city, and the company then added what is now known as the old pumping station, erected a standpipe on Kenoza Avenue, and began to supplement the gravity system by a high-service system. At the same time there was in the western part of the city a reservoir on Silver Hill, or Mt. Washington. This was supplied from springs and was the property of the Silver Hill Aqueduct Company, and was used for the purpose of supplying a little settlement of houses in that vicinity. The Haverhill Aqueduct Company at this same date acquired by purchase and deed this property.

In 1882 it became apparent that there was a permanence in the growth of the city which would require a greater supply than they were then enjoying, and the same year they went up to Crystal Lake and acquired the mill sites on the stream flowing from the lake. In 1884 the legislature granted them the right to use the water of Crystal Lake as a source of supply, and the company immediately laid its line of 16-inch cement pipe from Crystal Lake into the city. In 1889 the growth of the city on the high lands of Mt. Washington had continued and it was again necessary that the high-service system should be supplemented. Another standpipe was erected on a tract of land acquired for the purpose on Grove Street.

In 1884, owing to the dissatisfaction of some of the large water takers with rates, an agitation was made looking to the purchase of the plant by the city, under the Act of 1867; hearings were held by a committee of the city government, but nothing was at this time done. In 1890, however, another committee was appointed, with an appropriation of $500, to investigate and report on the advisability of acquiring the property and franchises of the Aqueduct

Company. After an exhaustive hearing, the formal order of taking was passed by both branches of the city government, and the order was approved by Mayor Burnham July 10, 1891. By this order the mayor was directed to apply to the Supreme Judicial Court for the appointment of three commissionars who were to determine the price of the franchise, rights, and property of the company. The Court appointed Hon. George O. Shattuck, John E. Sandford, and Weston Lewis as commissioners. They held their opening session May 14, 1892, and on the 17th day of October, 1892, the commissioners reported that the price to be paid by the city was $637 500, with interest from the 6th day of July, 1891; the city was also to pay the fees of the commissioners, which were fixed at $7 655.

The Aqueduct Company was represented by Hon. William Gaston, E. T. Burley, Esq., Boyd B. Jones, Esq., and Frederick E. Snow, Esq.

The counsel for the city were Hon. George D. Robinson, Hon. William H. Moody, and Edward B. George, Esq.

The total cost to the city of the hearings, including experts and counsel fees, was about $22 000.

The authority under which the works were taken by the city and have since been conducted was an act of the legislature, passed in 1891, and two supplementary acts passed in 1892 and 1896. These acts were drawn by Hon. William H. Moody, now one of the justices of the United States Supreme Court, who at that time was chief counsel for the city, and on the formal taking of the works was appointed one of the water commissioners. The original act was different from other acts regarding water supply in several particulars. Mr. Moody writes me that " the main purpose which I sought to accomplish, carrying out in this respect the wishes of the mayor and city council then in office, was to separate completely the water department from all other affairs of the city. It was hoped thus that the department would be managed upon strictly business principles without regard to politics. To that end it was provided that the water commissioners should be appointed for a term of five years, that only one should be appointed each year, and that the city be left to pay for the water which it used like any other consumer. The power of management of the

department was vested exclusively in the commissioners, subject to removal by the city council for cause." Mr. Moody further writes that "in the Act of 1892, which referred to the taking of lands for the protection of the water supply, I put into it the provision that any land taken for the protection of the water supply might be managed, improved, and controlled by the water commissioners in such manner as they should deem for the best interests of said city. The purpose of this provision was to enable the land thus taken to be used for the purpose of a public park, as it has since been. I hoped for good results, but I didn't realize that the result would be a most beautiful park in which all our people may justly delight."

Under this act the water board has taken 623 acres of land, at a cost of $157 432, the larger portion of this being about the storage basin and Kenoza Lake. A portion of this is placed under the control of the park department at the discretion of the water board.

For five years the city paid for the water used in all public buildings and drinking fountains. Then came the same trouble that so many water works have had to meet, — a city council short of money, — and the question was raised why, as the city owned the works, any rates should be paid. The matter dragged along for several years, but no adjustment was ever made, and the city has since then not paid a penny for water. In our case it has seemed particularly unjust, since not a dollar has ever been paid by the city towards buying the plant, operating it, or toward the sinking fund. We charge the owners the entire cost of putting in the service, and the city pays all bills of this kind for the different departments of the city.

Early in 1882 Haverhill was visited by a disastrous fire that reduced almost the entire "shoe district" to ruins. The next year the city council appointed a committee on water supply, authorized "to cause to be laid by contract or otherwise cast-iron pipe 12-inch in diameter, to be connected at the North Church with the high-service pipe of the Haverhill Aqueduct Company." This pipe was to be used exclusively for fire service, and was laid through the main streets of the city, taking in the retail section and that portion occupied by shoe factories. An appropriation of

$30 000 was made covering the cost, and the work was done under the direction of the committee. As the manufacturing district has expanded, calls have been made for extension of the high service in various parts of the city, to be used exclusively for fire protection, and appropriations have been made by the city council, the water department doing the work.

The hydrants are all under the control of, and are furnished by, the fire department, but are set by our department and the expense paid by the city.

The water commissioners have the right to fix the water rates; the income, after deducting all expenses and charges of distribution, is applied, first, to the payment of the interest on the bonds; second, to the payment of the sinking fund requirements (two per cent. of the total amount of the bonds); third, to the payment of all current expenses; fourth, the balance, if any, may be applied to the sinking funds in the discretion of the commissioners. We are also allowed to expend not exceeding twenty thousand dollars in any one year for the purpose of new construction. In case the surplus should not equal the two per cent. required for the provision of the sinking fund, the city must raise such sum by general taxation.

Our department receives all money from rates, etc., and pays its own bills, the only connection with the city being the appointment of a commissioner each year by the mayor, the auditing of the books of the department by the city auditor, and the payments for interest and sinking fund, which are made to the city treasurer. The result aimed at has been achieved, the department having been so far kept entirely out of politics.

None of the commissioners, with the exception of the chairman, receives pay, and up to the present the members of the board have all been leading citizens who have freely given of their time, and have been reappointed as long as they desired to remain upon the board.

The improvement and development of the system since its acquisition by the city have been on the lines laid down by the consulting engineer, the late Freeman C. Coffin, who in January, 1895, submitted an exhaustive report on the needs of the plant, and the sources of additional supply; and the result is a system

fully equipped and capable of supplying an abundance of pure water, at a cost to the consumer comparing favorably with other cities of the country. At the present time, a large section of the city is supplied by gravity from Crystal Lake, Round Pond, and Lake Saltonstall. Kenoza Lake supplies those portions of the city that are dependent on high service, and also furnishes water for the fire service, the water being pumped to a reservoir of 9 000 000 gallons capacity, built in 1898. As an auxiliary supply we have Millvale storage basin, which was built in 1894–5 by damming East Meadow River, and which has a capacity of 118 000 000 gallons. A Worthington engine with a capacity of 8 000 000 gallons per day is installed at Millvale, and the water is pumped through a 24-inch pipe into Kenoza Lake, a distance of one mile, as required to keep that lake at a proper height. A 16-inch pipe connects Kenoza Lake and Round Pond. At the new Kenoza station, erected in 1900, are two pumps, one made by the Barr Company, of Philadelphia, with a capacity of 6 000 000 gallons; another of like capacity made by the Platt Iron Works Company, of Dayton, Ohio.

In 1896 the town of Bradford, situated on the south bank of the Merrimac River, was annexed to Haverhill, and the Water Board took in charge the water system of that town, which had been installed by Messrs. Goodhue & Birnie, of Springfield, as a private enterprise, and later taken by the town. The water for this portion of the city is furnished from Johnson's Pond, with an area of twenty-two acres, and is all high-service, pumped to a reservoir of 1 000 000 gallons capacity by a two-million-gallon Deane pump. The water board is about to install a second pump at the plant, and eventually will probably lay a pipe across the river, which would be of use to either section in case of emergency.

We supply an estimated population of 37 600, our consumption being 134 gallons per day to each consumer. This high consumption is due to the fact that outside of the business portion of the city the use of meters has been optional, and at the present time we have in use only eight hundred meters. We have eighty-four miles of main pipe, cement lined and cast iron, ranging in size from two to twenty-four inch. The pressure on the low service ranges

from thirty-five to forty pounds, while the high service is from eighty to one hundred and twenty. The original cost of the works in 1891 was $720 504.17. The cost of the works December 1, 1907, which, of course, includes all the improvements above mentioned and the land purchased, was $1 466 594.51, while the net debt at that same date was $646 491.

And in addition, what is after all of the most importance to the water takers of the city, is the fact that since 1892 the rates have been year by year decreased. After several reductions in the tariff of rates, the commissioners adopted the policy of a discount of 5 per cent. for prompt payment of bills, and this has been increased to 10, 15, 20, and 25 per cent.

Like many another of the old landmarks, the log aqueduct long since passed away, and except perhaps as a matter of history, is no longer interesting. But the main fact remains, that we have to-day an institution that has survived since 1802 and has developed to its present condition. Started by some of the leading men of the time, identified with the growth of the old town, it certainly was not altogether for what there was in it. For years its earnings were small and less than the expenses, and even after its reorganization, for a long period no dividends were paid, and assessments on the stock were made. And not only that, but the task was a thankless one. The community viewed the venture as chimerical, and the individuals engaged in it as foolhardy in the extreme. The town scoffed at the idea, and the multitude believed that there was not then nor ever would be any use for such a contrivance as an aqueduct.

Who can say to-day how much the existence of the facilities for water afforded through the past history of the town and city, and due largely to the enterprise of these townsmen, has contributed to its progress and present prosperity?

DISCUSSION.

Mr. M. N. Baker. Mr. President, I think we are all agreed that this is a unique contribution to the history of American water works, and that the author of the paper is to be thanked for having taken so much pains to bring together such a large amount of valuable historical matter. It would be a very fine thing if others

in position to do so would follow his example and put on record the history, in so far as it has not yet been done, of at least those water works that were built up to the early part of the nineteenth century. The number of works, as has been stated in the paper, in operation up to the close of 1800 is small. Even well into the nineteenth century, there were only thirty-two works. I hope that it will be feasible to reproduce in the JOURNAL some of these very interesting historical documents which Mr. Sawyer has shown us. I am sure they would be of great interest to all the members of the Association, and of value to others outside of the Association who may wish to refer to the JOURNAL in the years to come for just such matter as this. Those of us who have attempted to make similar investigations know how difficult it is to bring together material of this sort, and I think it is very rare indeed to find such complete records, covering a period so long past.

BULLETIN OF THE HOQUIAM WATER COMPANY, HOQUIAM, WASH.*

BY HARRY C. HEERMANS, PRESIDENT.

CHEAP TRANSPORTATION AND DELIVERY OF PUBLIC WATER SUPPLY.

Examine the tables in this bulletin. They will agreeably surprise you. Please remember in paying your water bill that you pay for the collection, pumping, and delivery of an adequate water supply, *when* you want it, *where* you want it, and in quantity to supply your requirements. No worry. Your rate is based on the quantity required for the uses you specify in your application to the water company. You do not pay for wastage and you are, therefore, requested to treat the company fairly and prevent waste. That is the only square deal. Think of the luxury and cheapness of a public water supply. You make no investment for wells, or cisterns, or storage tanks; no labor at home pumping water or cleaning cisterns, wells, or tanks, and no payment of constant repairs to the same. The public supply furnishes your home with hot or cold water everywhere if you want it and is the cheapest commodity you buy.

Think of these facts and *smile* when you pay your bill to the water company.

COST OF WATER, DELIVERED BY WEIGHT, ACCORDING TO VARIOUS RATES, THROUGH WATER-WORKS SYSTEMS.

Attention is called to the fact that the delivery of water by weight, through public water supply systems, as a commodity, is the cheapest in the known world, in comparison with other transportation; for instance, the switching of a car containing fifteen tons of freight, switched within the city limits by any railroad company, would not be less than $2.00, or 12⅔ cts. per ton.

Last summer the Hoquiam Water Company paid for the switch-

* This bulletin is reproduced for the benefit of water-works managers generally.—Editor.

ing and transportation of carloads of water pipe, a distance of not over two or three miles, the sum of $15.75 per car, or .877 cts. per ton (wire banded wood pipe).

We are now collecting the Hoquiam water supply at the average distance of five miles from town, pumping and delivering the same to consumers in their homes at any elevation required, not exceeding 200 feet above sea level, at the rates per ton as shown in the following table:

Prices per 1 000 gallons delivered through water-works systems..............	$0.08	.15	.20	.30	.45	.50
Prices of water per ton, delivered by various water companies............	$0.019	.036	.048	.072	.107	.119

One thousand gallons of water weighs 4.175 tons.
One gallon of water weighs 8.35 pounds.
One cubic foot of water weighs 62.42 pounds. — (Trautwine.)
One cubic foot of water contains 7½ gallons.

THE REASON WHY WATER TAKERS SHOULD PREVENT LEAKS IN PLUMBING FIXTURES.

[Data taken from book on hydraulics, by Geo. A. Ellis, C. E.]

Amount of water, in gallons, that will pass through pipes or jets of various sizes in one hour under different pressures of the Hoquiam Water Company:

Size of Openings.	85 Pounds Pressure.	90 Pounds Pressure.	95 Pounds Pressure.	100 Pounds Pressure.
1-16 inch.......	64.2	66	67.8	69.6
1-8 „	258.6	265.8	273	280.2
3-16 „	577.2	593.4	612	624
1-4 „	1 032	1 062	1 090	1 122
3-8 „	2 310	2 376	2 442	2 502
1-2 „	4 128	4 248	4 368	4 476
5-8 „	6 420	6 600	6 780	6 960
3-4 „	9 300	9 600	9 880	10 080
7-8 „	12 600	13 020	13 380	13 680
1 „	16 500	16 980	17 460	17 940

The following acts are prohibited:

1. Allowing water to run to waste, or to run to prevent freezing.
2. Having leaky water fixtures on the premises.
3. Using a hose without a nozzle.

4. Using a nozzle with an orifice of more than one fourth of an inch.

5. Using water through a hose unless hose is held in hand.

6. Using water through a hose between the hours of 9.00 A. M. and 5.00 P. M.

7. Using an automatic sprinkler at any time unless such sprinkler is connected on a meter.

8. Using water through a hose during the progress of a fire in the city, except upon the fire.

9. Using water through any plumbing fixtures without first applying for and obtaining permission for such use.

10. Allowing water to be taken from premises by persons having no right to its use.

11. Willful waste of water in any way.

PRIVATE FIRE PROTECTION AND INSURANCE RULES.

BY GORHAM DANA, MANAGER, UNDERWRITERS' BUREAU
OF NEW ENGLAND, BOSTON, MASS.

[Read November 11, 1908.]

In the work of laying out private fire protection for manufacturing and mercantile buildings, the insurance engineer frequently meets with opposition from the water departments. From my experience in this work, covering nearly fifteen years, I think it safe to assume that most of the water-works superintendents look upon an insurance engineer as an unreasonable fellow, who has all sorts of ridiculous rules, and whose main object is to get all he can out of the water department for himself or his client without giving anything in return.

It occurred to me that a frank explanation of the scope of our work and the reasons for our requests might put them in a better light before you and clear up some of the past differences in opinion.

As a matter of fact, the insurance engineer is not as unreasonable as he may appear. What he asks is from no selfish motive, for improved protection means lower insurance rates and less income for the insurance companies. The average local insurance agent prefers not to see sprinklers installed in the buildings he insures, for it means less premium to him.

What the insurance engineer does for one plant or individual is of benefit to the whole community, for it means lessening the chance of a serious fire, and, therefore, lower insurance rates for all.

The rules that he works under are no arbitrary rulings made by himself or by his manager, but they are National Standard rules drawn up by committees of the National Fire Protection Association. These committees are composed of men from all over the country and represent the experience and best thought of the brightest men in the business.

First of all, I should like to touch on the need of private fire protection, more especially automatic sprinklers, as a means of

reducing the annual fire loss of the country. That there is a need of reducing the fire waste must be apparent to any one who reads the ever-increasing list of fires in the daily papers. The total loss for the last thirty-three years has been four and one-half billion dollars. The average loss for the last few years has been almost two hundred and fifty million dollars. In other words, this loss is going on day and night at an average rate of $500 per minute. This is a direct and real loss to the community, the insurance only distributing the loss amongst many, and not really paying it. To this should be added the indirect loss of some $350 000 000 a year, due to the cost of maintaining fire departments, insurance companies, protective departments, fire-service mains, etc., so that the total fire tax to the country is something like $600 000 000 per year.

But the most discouraging feature of the situation is the fact that this loss is increasing each year by leaps and bounds. In 1875 the loss was only $78 000 000; in 1885 it was $102 000 000; in 1895 it was $142 000 000; in 1906 (the year of the San Francisco conflagration) it was $500 000 000. The loss for August, 1908, is estimated at $23 000 000, or $3 000 000 more than for August, 1907; and for September, $22,000 000, or $9 000 000 more than last year. That this country is far ahead of any other country in fire waste is shown by the fact that the loss per capita is $2.47, while in Germany it is 49 cents, in Italy it is 12 cents, and the average for European countries is 33 cents.

With these astonishing figures staring us in the face, is it not the duty of every one, water-works man, insurance man and all, — to do all in his power to reduce this ever-growing tax?

A large part of this loss occurs in our cities. American cities are growing at a tremendous rate, especially vertically, and our fire-fighting facilities are not keeping pace with the growth. This was well illustrated in the Parker Building fire in New York last winter. Here was a modern twelve-story building of so-called fireproof construction, but used for printing and similar purposes, and containing a large amount of combustible material. To be sure, it had the serious defect of large unprotected stair and elevator openings, but this is a defect that is very common in modern buildings. Fire started and gained some headway before being discovered. The

fire department responded promptly, but was utterly helpless above the eighth story and the fire on the upper floors practically burned itself out.

With this condition confronting us, what are we to expect in a twenty, thirty, or forty-two story building? So long as they are used for offices only, they are comparatively safe, but when filled with combustible material they can no longer be considered fireproof, even though the structures themselves are properly built.

If a conflagration should sweep lower New York, the loss would be in the billions, and probably every insurance company in the country would be put out of business. A panic would result such as the country has never seen.

What is the remedy for this state of affairs? Surely, a fire department now helpless above the eighth story cannot, for many years, at least, be developed so as to be effective at elevations of twenty and thirty stories. The remedy to my mind is the automatic sprinkler.

AUTOMATIC SPRINKLERS.

Sprinklers came into general use about twenty-five years ago, or in the early eighties. Since then they have been steadily improved, until now they have reached such a state of perfection that but little further improvement can be looked for. It is estimated that about 25 000 000 sprinklers have been installed in this country, representing an investment of almost $100 000 000.

Briefly stated, automatic sprinklers are small valves held closed by soft solder, melting at about 160 degrees. When opened, they distribute water by means of deflectors. They are placed throughout a building, 6 to 12 feet apart, and attached to pipes containing water under pressure. In unheated buildings, they are placed on the so-called dry system, a dry valve being introduced to hold back the water until a sprinkler head opens.

For twelve years the National Fire Protection Association has been collecting statistics on fires occurring in buildings equipped with automatic sprinklers. Six thousand and forty fires have been tabulated, and in 93.77 per cent. of these the sprinklers extinguished the fire or held it in check. In the other 6 per cent. they failed, but there was usually some good cause, such as closed

valves, empty tanks, etc. In 65 per cent. of the fires, 5 sprinklers or less opened; in 78 per cent., 10 sprinklers or less opened; in 91 per cent., 35 sprinklers or less opened.

Under normal conditions, sprinklers put out a fire with much less water than would be used by hose streams, and it would seem that for this reason alone water departments should welcome the introduction of sprinklers and do all they can to assist the insurance engineer in laying out a proper equipment.

RULES.

A few words about the rules for installing sprinklers may be of interest to some of you. Sprinkler systems to warrant the lowest insurance rate should have two independent sources of supply, so that if anything happens to one there will still be something to fall back upon. The ordinary supplies used are water-works connections, gravity tanks, pressure tanks, and various kind of pumps. Where pressure and volume are adequate, water-works systems are always considered the most desirable supplies. In fact, in large cities, where the public water supply is first-class, a proper sized connection from such a system is usually considered as good as a tank and pump supply in the country. There should be a pressure of at least twenty pounds on the highest sprinklers to give good protection. The size of main connections and risers is figured large enough to supply the sprinklers on one floor only, the theory of sprinkler protection being that they will control the fire on the floor where it originates. To this end great care is taken to enclose all floor openings, such as elevators and stairs, so that fire cannot readily spread from floor to floor.

The pipes on each floor are graded according to the number of heads supplied by each. The rules for these sizes have been evolved during the last twenty-five years from actual experience and tests. They were changed in 1896 and again in 1905, the sizes being enlarged both times, but the rules as they stand to-day will probably not need any further change of any importance, at least for many years. At present, a 4-inch pipe can feed 80 heads; a 5-inch pipe, 80 to 140; and a 6-inch pipe, 140 to 200 on a floor. Two hundred is as many heads as are often found on one floor between fire walls, and where this number is exceeded, two or more connec-

tions are generally called for. The distance apart that heads are located varies greatly with the construction, but one head to 80 square feet is a rough average.

SIZE OF CONNECTION.

Some water departments object to allowing the proper size connection where the street main is small. This seems to me unwise, for in case of fire, water must be used, and sprinklers will put out the fire with less water than hose streams. If the connection is not large enough, the sprinklers may fail to do what is expected of them and hose streams will then have to be used in addition. Therefore, it appears to be economy for the water department to allow the proper size of connection, no matter what is the size of main.

In some cases a ruling has been made that no connection over four inches in size can be made, although more than one such connection can be had where necessary. This seems to me to be an unnecessary hardship on the taxpayer. In the first place, it generally introduces another gate and check valve, which adds to the expense as well as introducing another chance for trouble, due to valves being closed by mistake. It also means more friction loss.

The only reason I have heard for such a rule is that there is less chance of waste in case of a break. I fail to see why this is so, for if two 4-inch connections entered a building and were brought together to feed one 6-inch riser, a break in this riser would be fed by two 4-inch, pipes, which have a capacity of practically the same as one 6-inch, and in case of a break in the 4-inch, the water would come from each direction and would again be about the equivalent of one 6-inch. As a matter of fact, the chance of breakage in one of these large pipes is extremely small, and it would seem that the benefit from a good sprinkler system would more than offset any possible danger of wasting water at a time when it was needed elsewhere.

Another feature to be considered is the additional cost in case sprinkler supervisory apparatus is installed.

SPRINKLER SUPERVISORY APPARATUS.

Sprinkler supervisory apparatus has only been on the market about two years, but many equipments have been installed in

the larger cities, like Chicage, New York, and Boston. It has already proved its worth and undoubtedly has an important future. Briefly stated, the idea is to affix electrical contacts to all gate valves and other parts of sprinkler systems, in order to give an alarm in case any device is put out of order. Thus, the attachment on a gate valve (Fig. 1) gives an alarm in case the valve is

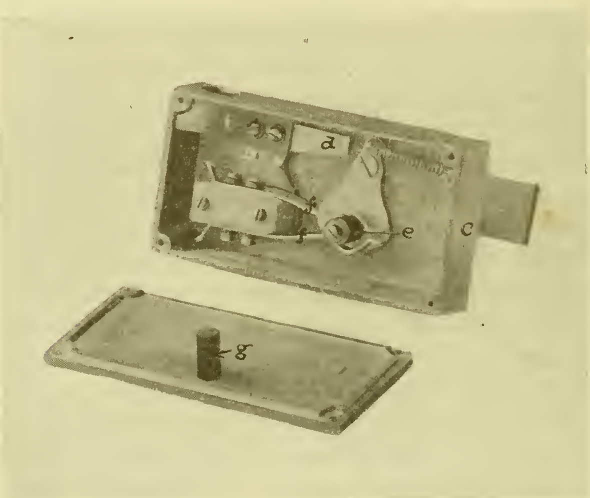


Fig. 1. A. D. T. Co. Gate Valve Attachment.

c = case; d = case contact; e = rubber roller; ff = German silver springs; g = post for closing case contact.

This is designed to attach to a gate valve so as to give an alarm as soon as any one starts to close the valve.

turned more than a fraction of a turn from the position of wide open. The attachment on a gravity tank gives an alarm in case the water level drops below a pre-determined point or in case the temperature gets too near freezing (Fig. 2). The attachment on a pressure tank gives an alarm in case the pressure or water level drop too low. The attachments are so made that they cannot be tampered with and the wiring is on a closed circuit and enclosed in conduit. The wires run to a central station where there are men on duty at all times. In case an alarm comes in, a runner is sent

to see what the trouble is and to remain until it is remedied, when necessary.

With such an equipment, it is almost impossible for a sprinkler system to become crippled in any way, without the trouble being discovered and remedied at once. The chance of sprinkler failures should thus be reduced to almost nothing.

Now each contact, that is, the attachment to gate valve, tank, etc., costs from $25 to $40 a year, and any extra valves required by water departments become a serious question financially. Furthermore, on account of the large number of sprinkler valves that are left closed accidentally where there are no such attachments, the underwriters prefer that as few as possible be installed.

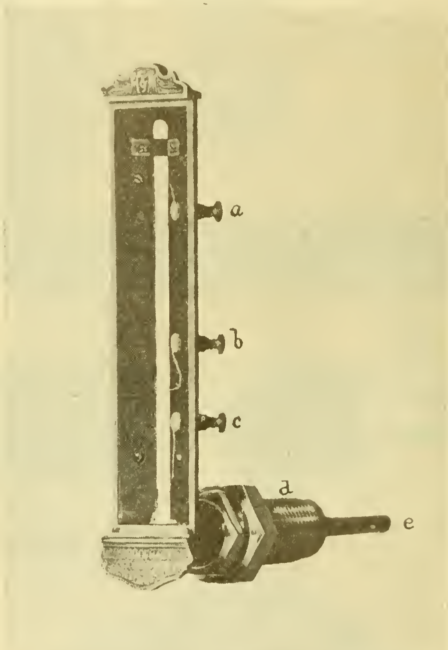


FIG. 2. A. D. T. TEMPERATURE DEVICE.

a = high-temperature contact binding post; b = low-temperature binding post; c = constant binding post.

This is designed to attach to a gravity tank to give an alarm in case pressure nears boiling point or freezing point.

METERS.

A few water departments in New England are requiring meters in private fire pipes. The underwriters are opposed to this practice on account of the numerous complications it introduces, principally friction loss, chance of clogging, and a considerable extra expense. It is true that the so-called detector meters have overcome the trouble of complications to a large extent, but they are expensive, especially in the larger sizes.

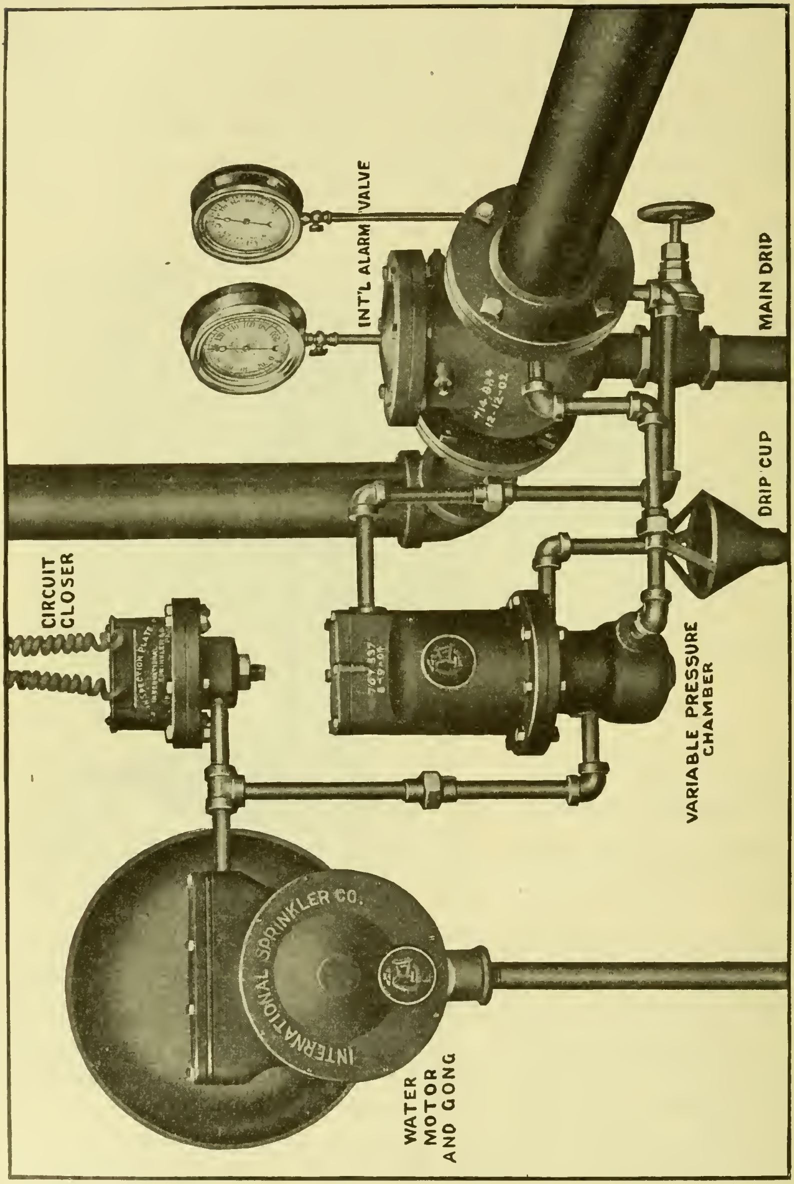


FIG. 3. INTERNATIONAL ALARM VALVE (GENERAL VIEW).

I realize that water is sometimes stolen from sprinkler systems, and that it is the duty of the water department to put a stop to it, but I believe there are other methods of accomplishing this result which are better from a fire protection standpoint.

In the first place, the insurance rules do not allow sprinkler pipes to be used for any other purpose. All water departments should have a similar rule and should enforce it rigidly. In addition, they may seal all drip valves and private hydrants and require that they be notified if a seal has to be broken for any reason. This is done in some cities, and, so far as I know, has successfully prevented any serious trouble.

Few people will steal water willfully. The trouble is generally caused by some engineer or mechanic who taps a fire pipe thoughtlessly, without realizing what he is doing. A pipe cannot be readily tapped without shutting off the water, and this would be brought to the attention of the department by the breaking of seals.

ALARM VALVES.

Nearly all modern sprinkler systems contain alarm valves. These constitute one of the best safeguards against taking water from sprinkler pipes that there is. There are at present two approved alarm valves on the market, the Variable Pressure or English Alarm Valve, made by the General Fire Extinguisher Company, and the International, made by the International Sprinkler Company. The principle in each is similar, namely, a check valve that when on its seat closes a groove or pipe outlet, and when off its seat allows water to flow into the groove or pipe. This water is used to give an alarm by operating a rotary or water motor gong, or by pushing up a diaphragm which gives an electric alarm. Alarm valves have been developed so that now they are very reliable, and furthermore, unlike the older types, they seldom give false alarms. The "International" and "Grinnell" alarm valves are shown in Figs. 3, 4, 5, and 6.

Now an alarm valve placed in a sprinkler pipe is, to my mind, just as good as a meter. No water can pass through the pipe without giving an alarm, provided the alarms are in order. The insurance inspectors go through the plant several times a year

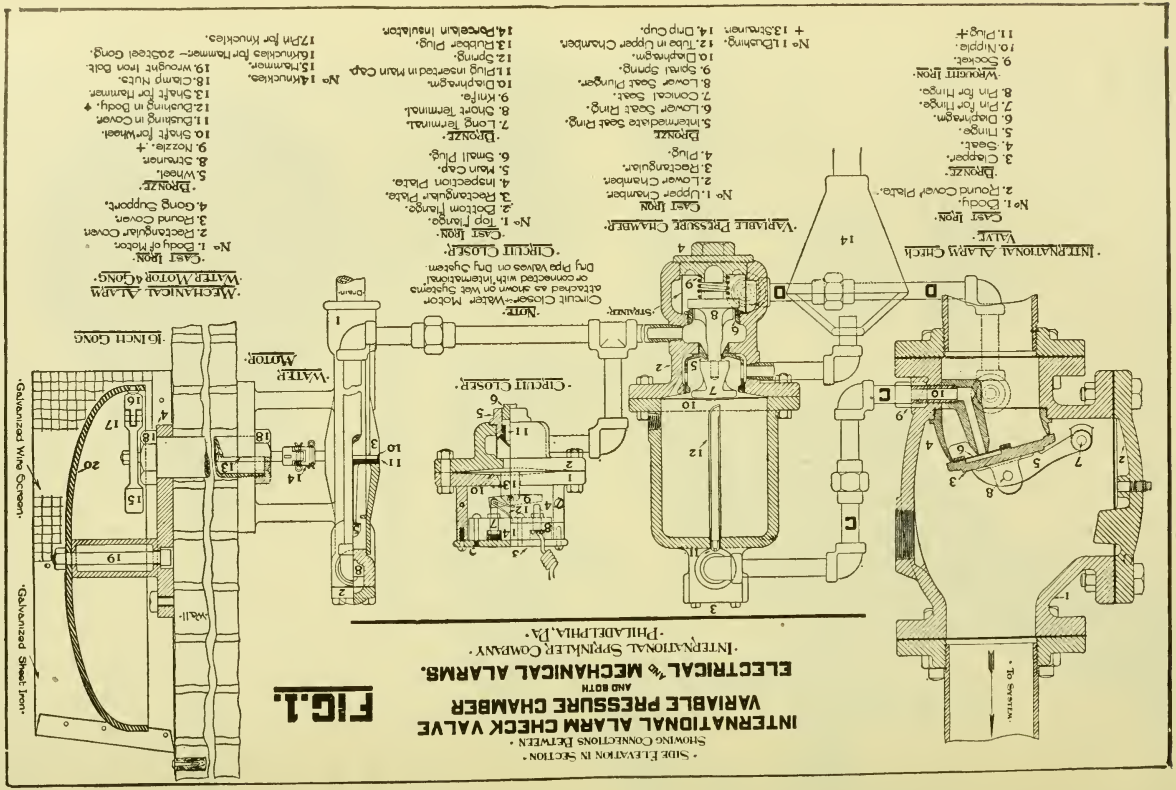


FIG. 4. INTERNATIONAL ALARM VALVE (SECTIONAL VIEW).

The swing check valve 3 tightly closes the outlet of pipe C when on its seat. When the check opens, water flows through pipe C to variable pressure chamber, hence to electric circuit closer and water motor.

to see that these are kept in order. In cities where there is sprinkler supervisory, such devices can be supervised from a central station, in which case a trouble signal is received if any part of the system gets out of order. If further proof is needed, small-sized meters ($\frac{1}{2}$ or $\frac{3}{4}$ in.) can be placed in the pipe that runs to the alarm connection. In this case, no water can be drawn through the sprinkler pipe without registering on this meter. This does not give the actual amount passing through the system, but the proportion could be roughly figured. In case there is a rule forbidding the use of any water, the amount is not important, for the rule is broken and the person who does it can be punished.

Still another method of checking up the flow of water in a sprinkler system is to place a recording pressure gage on the pipe from the alarm valve. Ordinarily there is no pressure in this pipe, the inlet being closed by the check valve. In case of flowage, the pressure will be recorded on the gage and the exact length of time that it occurred can be ascertained from the dial.

CHARGING FOR FIRE PIPES.

In some localities an annual charge is made for sprinkler connections from water-works systems. It might be argued that this is something that should not interest the insurance engineer, but anything that adds to the expense of a sprinkler equipment interests the insurance engineer, for it is his duty to keep the cost of such equipments as low as possible, so that they may be more generally installed and thus cut down the fearful annual fire waste.

Where a water-works system is owned by a town or city and supported by public taxes, there appears to be no more reason for charging for private fire service than for public protection. It may be thought best to make the property owner pay for the original cost of installing such a connection, but it certainly seems wrong to charge him any annual rental. This is, of course, assuming that the fire service pipes are used for fire protection only, as they should be.

The property owner is entitled to public fire protection on account of the taxes he pays. If he chooses to put in at considerable expense private fire protection that will put out a fire

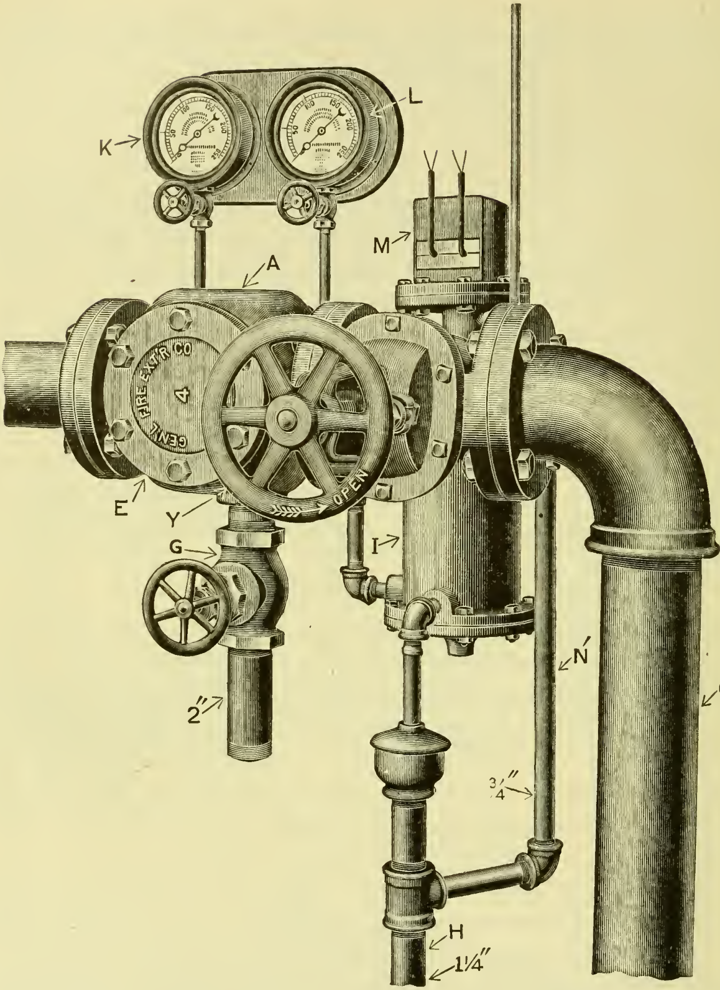


FIG. 5. GENERAL VIEW, GRINNELL VARIABLE PRESSURE ALARM VALVE.

with the use of much less water than would be used by fire department, it is certainly not fair to make him pay the community for so doing.

Where the water system is owned by a private corporation the problem is somewhat different. In this case the town usually

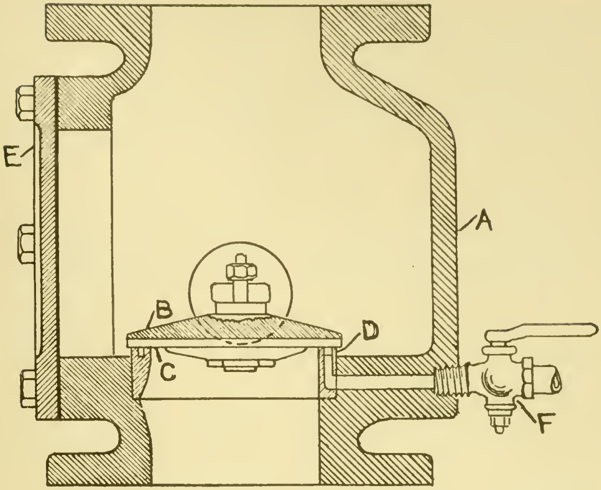


FIG. 6. SECTIONAL VIEW, GRINNELL VARIABLE PRESSURE ALARM VALVE.

The swing check valve *B* when on its seat closes groove *D*. When check opens the water flows through groove and pipe *F* to rotary bell and electric circuit closer (not shown).

pays the water company a given amount per year for each hydrant. Now there seems to be no reason why the private connection should not be placed on the same basis as hydrants in this case, too. If a mill owner should ask for more public hydrants near his plant, they would be supplied without cost to him. If, therefore, he asks for a sprinkler connection which will put out the fire with less water, why should he not be supplied with that, too, at the town's expense? As in the previous case, this is on the supposition that the sprinkler connection will be used for fire purposes only. The regular service connection should be entirely separate. If he desires more yard hydrants, these, too, might be well supplied at public expense, at least, so far as annual rental is concerned, for such hydrants are simply an extension of the pub-public hydrant system, and this he is entitled to if he pays taxes.

Now as to the best basis for payment for fire service connec-

tions where the water system is owned by a private corporation, — for it is certainly fair that some payment be made, whether it be by the town or by the property owner:

In the past, systems have often been charged for on a basis of so much per sprinkler. This is unfair for the reason that sprinklers are installed on the theory that only one floor will be on fire at once. Sprinklers will almost always control a fire before it spreads to another floor, and if they do allow it to spread to this extent, the chances are that they will not control it at all. The same size connection and riser is allowed for a ten-story building as for a one-story building, provided the floor areas are the same. Only so much water can be obtained from a given sized pipe, whether it supplies ten stories or one.

Another method favored by some water companies is to charge a certain proportion of the insurance carried or a proportion of the reduction in rate allowed by the insurance companies for the protection. This is also unfair. It might be that a large part of the insurable value at the plant was in storehouses that contained no fire protection. Again, the reduction in rate for improved fire protection is not based on the protection afforded by public water connections only, but also on private water supplies, such as pumps and tanks, upon private brigades, private hose, watchman's service, and numerous other features.

The fairest basis for the charge would seem to be that of the number and size of connections, for it is this that determines the amount of water that could be used in such a system.

It would seem fair to consider a 4-inch connection as about the equivalent of one hydrant, for this is the smallest size of pipe permitted for a hydrant supply. On this basis a 6-inch pipe would be the equivalent of two hydrants, and an 8-inch pipe to four hydrants, a 10-inch to six hydrants, etc., this being figured on the relative area of these pipes. If, therefore, the price charged per hydrant be taken as a standard, and the sprinkler connection figured on the above basis, we would have a simple method of computation, yet one that is fair both to the property owner and the water corporation.

Finally I would impress upon you the need of coöperating with

the insurance engineer in his campaign to reduce the $500 per minute fire waste of the country. Do nothing that will discourage automatic sprinklers or make equipments more expensive, for in them lies one of the greatest safeguards against serious fires and conflagrations.

DISCUSSION.

Mr. Andrew D. Fuller.* I should like to ask Mr. Dana what the objection would be to metering the fire service where you have a tank.

Mr. Dana. There is no objection to metering the supply which fills the tank, but for the supply which goes directly to the sprinklers, of course, the pipes have to be large pipes, 4 to 6 inches, and that means an expensive meter and friction loss and possible clogging in case of fire.

Mr. Fuller. Then a person could have a sprinkler system installed, and pay for the amount of water necessary to fill the tank in the beginning, and then, if the direct supply was metered, he would not have to pay for any more water unless there was a fire. Would it not be practical to have the water company buy the large meter and charge a certain amount of rental a year, to cover depreciation, etc.? Would that cost more than the saving in rates?

Mr. Dana. Of course it can be done, but what we claim is that it is not necessary, as there are other methods of getting the same results which are cheaper and, from our standpoint, better. We want to keep the cost as low as possible.

Mr. Charles W. Sherman.† What Mr. Dana has said about the parties who pay taxes being entitled to the fullest measure of fire protection seems to call for a little comment. As far as my knowledge of them extends, most public water systems receive no help from the tax levy; they are entirely dependent for their operating expenses and for their contributions to sinking fund upon their water rates. Therefore no taxpayer *as such* is entitled to fire protection, since he is not paying for it. To be sure, the plant belongs to the community, which has loaned its credit for

* Civil Engineer, Boston, Mass.

† Principal Assistant Engineer, with Metcalf & Eddy, Boston, Mass.

the purchase or construction of the plant, but otherwise to all intents and purposes it has no ownership in the system. The water takers are the people who must foot the bills for the operating and maintenance expenses and the contributions to the sinking fund to extinguish the indebtedness.

Now, under those circumstances, as I said before, no taxpayer as such has any right to claim fire protection from the water-works. We are accustomed to furnishing it, and I do not see how we can very well change the conditions which confront us, but as a matter of equity a certain percentage of the necessary running expenses of the water system should be contributed from the tax levy to the water department. That would mean, of course, lower water rates to the private consumers, in order to get an equitable distribution of the operating expense between the water customers and the general public who should pay for furnishing fire protection.

Mr. Elbert E. Lochridge.* I should like to bring out a point or two in connection with this discussion. As water-works people we have all heard the claims of the insurance engineers, and I think that water-works people in general are anxious to meet them. To carry out Mr. Sherman's point a little further, in any system the revenue is derived from money paid for water used, and the largest consumer in most cases, under the prevailing system of rates, pays the least proportionally; that is, he gets his water cheaper than the small consumer. The fire protection is purely an outside matter, which, in most cases, is not paid for by the municipality except as its credit is loaned, although hydrants and larger pipes must be put in, which are not necessary for the domestic supply but are only needed in case of fire. For that reason it seems to me perfectly fair that people who are directly benefited in their property should pay a certain amount for that particular benefit.

To take up another point, which has not been brought out directly, when the insurance engineer comes to the engineer or superintendent of the water department and asks for these things, he doesn't quite see why it is that we can't grant them, and we don't see why our rules, which are for the benefit, as we see it,

* Chief Engineer, Springfield, Mass., Water Works.

of the entire city, are not as just as their rules; — for instance, their rules that there must be two supplies, and particularly that certain sizes of pipe should be furnished. Now, I want to say that in our reconstruction there have been a number of insurance engineers who have done everything they could to help us and who have arranged their plants in such a way as to insure safety as far as possible; however, there are some who do insist on points of which we cannot see the justice.

For example, two systems of water supply, as has been touched upon here already, are required by the underwriters. The city is under obligation to its citizens to furnish plenty of water for domestic purposes, and to have that water pure. Now, if a fire insurance company insists on two supplies, and allows the insured to pump from the Merrimac or the Connecticut River, or any other supply that is near the plant, as they do, and pump this against a check-valve, doesn't it seem reasonable that the company should also insist that these devices which have been described should be put on? But these are not put on in a great many cases, and so far as we are concerned personally we are having considerable trouble in getting some of them put on. I think we shall succeed in time. There is a constant menace in the testing of the pumps which, as they usually say, they simply turn over, but when you look at their dials you see that they usually go higher than the city pressure, or they do occasionally; and it seems to me perfectly reasonable that if these systems are to be thus connected it should be the duty of the insurance people to see that they are so connected that no impure water should go in for the use of the people employed in the mill or should go to the mains in the immediate vicinity of the mill.

I want to take up, also, not for the sake of argument but for the sake of putting forward the other view, the question of limiting the size of the pipes which go to the fire services. I don't care to consider the question of the actual sizes which should be used, but I think it is perfectly reasonable that pipes should be limited in size, and if greater capacity is needed I think it is perfectly reasonable that more pipes should be installed. If we have in the street an 8-inch main and an 8-inch connection, and the fire spreads beyond the immediate building in which the sprinkler

system is installed, we are under obligation to the other taxpayers and to the other water users to protect their property, and it is a serious thing when a large connection is left open on a street where the gridironing system is not perfect, — and in most of our New England cities it is not perfect in all parts of the factory district. On the other hand, it is probable that with two or more openings they be so placed that even with an advancing fire one of them may be shut off, and it is also possible that as the fire advances both of them may be shut off; and if you can reduce the opening to a 4-inch or a 6-inch instead of having it the full 8-inch, you have gained that much. I believe that the sprinkler system is of great value, and I think that the water-works officials should be ready to meet the insurance people half way, but I believe also the insurance engineers should meet the water department half way in its efforts to meet the demands for pure water, and in its demands that the least amount of water possible should be furnished for private fire protection alone.

Just one other point which occurs to me, and that is that the factories using fire supplies do not willfully take water. I think that the only thing we can fairly say is that they may not *willfully* take it, but if you go about you will see that they do take it, and every water-works man present knows that they take it in pretty large quantities. When we go around with our inspectors we know there are some very decided uses. It seems to me, then, that the insurance engineer should be ready, when asking for the concession of no meters and larger pipes, to furnish such guarantees to the water department that the department would not always be regarding these requests with suspicion, with the knowledge that in the past a great deal of water has gotten by.

Mr. Dana. Mr. President, I should like to reply very briefly to Mr. Sherman. The main point in regard to cost and charging to my mind is that of putting private service on the same basis as public service. Whether or not an abutter should pay for hydrants I do not know, and I am not discussing that; but I do claim that if he does not pay for hydrants he should not be asked to pay for a connection to his building which will put out a fire with less water than he would take from the hydrant.

Mr. Edwin C. Brooks.* Mr. President, I have sometimes thought that some of the trouble in regard to sprinkler systems might be solved by putting in composition check valves. The body of a check valve, as ordinarily made of cast iron, is barely large enough to let the valve operate, and the least formation of tubercles on the inside of the body is liable to arrest the opening or closing. Now a composition check valve would not be a very expensive luxury, and it seems to me it would be a step in the right direction in solving the trouble arising from check valves sticking open. Any one who has ever had much experience with check valves knows that they are an invention of the devil, and at best they are a very poor contrivance.

Mr. Edward V. French.* Mr. President, I used to come here simply as an insurance man, and I got pretty good treatment then, though generally not a great deal of agreement. I am glad to come to-day more as one of the brotherhood, for as one of the members of the Water Board down in Lynn I think I have had enough trouble during the last year or two to feel pretty secure in the ranks, — and the trouble is not over.

I would like to emphasize a little one point which Mr. Dana made in answering Mr. Sherman. Mr. Sherman's points are, I think, entirely right, if you analyze this question of charges for fire service down to the final limit, but his suggestions are not feasible, apparently, under present conditions of organization, as Mr. Sherman himself really intimated. I have brought up this illustration before, but I think it makes the thing clear. Take any one of our cities, and suppose at one end of the city there is a manufacturing plant that has no fire protection of its own, and simply depends on the public water supply. If that establisbment gets on fire, there isn't anybody here who questions that it is the duty of the public fire department to go down there and throw water on that plant for six or eight hours, or longer if necessary, and to use all the water that they can get; and frequently, where the fire has to be extinguished by such methods, the amount of water used is large. Now, supposing at the other end of the same city there is a progressive sort of a manufacturer, who has listened to some of the

* Vice-President Arkwright, Mutual Fire Insurance Company, and member of Water Board, Lynn, Mass.

ideas of men like Mr. Dana and put in private fire protection. If he has a plant that is worth $500 000, the chances are that he will have spent $20 000 of his own money for fire protection. He goes to the city and asks merely for a connection to supply his sprinklers with water, and immediately there is a desire to charge an annual amount for the service. Now the fact is that this manufacturer after spending his own money for protecting his plant is very much less likely to use any considerable amount of water than the man at the other end of the town who has no protection whatever. So that, as a matter of equity, with our present method of charging, it really is not fair to charge a man who is progressive enough to put in a fire equipment, which means merely better tools for using the water that is there, and let the man at the other end of the town have all the water that can be thrown on his plant without making him any charge whatever.

I am perfectly ready to agree — and I wish in our own case we could get something out of the tax levy—that it would be equitable to have the water department paid so much from the city funds for the fire service which it renders. Until that can be done, however, it isn't really fair and equitable to ask a large yearly payment from the man who puts in protection for the connection he desires to supply his equipment, and let the other man who perhaps does not pay any more to the water department get his fire protection perfectly free. It is simply a question of the equity of the thing under the present imperfect arrangement of charges.

Now just a word as to what Mr. Lochridge has said. I generally agree pretty well with Mr. Lochridge, and I think we will agree in this case. The real cardinal point about the sizes of connections is this: In order to make the sprinkler equipment at all efficient, you have got to furnish a fair amount of water at the outset of the fire. Fires that open 25 to 50 sprinklers are not uncommon. I have a list here of a good many fires in the last year and a half which opened over 25 sprinklers. Now 15 gallons per sprinkler is about the minimum, so that 50 sprinklers would take 750 gallons,— and we have rather taken for the average size plant 750 gallons a minute as about a fairly good water supply, if it can be delivered at a pressure of, say, 10 or 15 pounds at the highest head while the

sprinklers are discharging. If you stop to figure you will find that a 4-inch pipe, which will generally be 50 feet long between the street main and the fire service, together with the check valve and a gate and perhaps one or two elbows, will cause a loss of about 25 pounds pressure with 750 gallons per minute flowing. If, on the other hand, the service is 6-inch, the pressure loss comes down to a few pounds. Again, if you have a larger plant which may require, say, 1 500 gallons a minute, the loss in a 4-inch pipe would be in the vicinity of 100 pounds, which is absolutely prohibitive.

I agree fully with Mr. Lochridge that it is the duty of the water department to safeguard the whole system, but you never can do it perfectly, or even very efficiently, by simply putting in small-size connections. I think the rule should be to limit the connection reasonably to a size which would give the water needed in the particular case, and then get safety by requiring such a location of these connections and such controlling valve, that the valve can be gotten at and the water shut off in case the building falls.

In a great many factory plants the water goes into a system of yard pipes and is there distributed to the buildings, and every sprinkler connection has an outside valve, so that all use of water can be controlled. In the more compact sections of a city where there are built-up districts, so that you cannot do this, I think it would be possible for water departments, and perhaps this Association can help in that line, to develop some standard method of outside valves, marked in some standard way, so that it would be known as an outside controlling valve, and then locate those with a little study in each special case, so that they could be reached properly. This, I think, would give the protection needed, and is really the only way to get it in a thoroughly safe manner.

Mr. Brooks brought up another interesting point, which Mr. Lochridge touched on also, and that is the check-valve and its diabolical origin. I think he is entirely right about it. We have given this much study, and it is possible to get a check-valve of better design, with more clearance, so that tubercles cannot easily obstruct it, and with better hinges, etc. We have given a good deal of attention to having such a check put on the market and are using such improved patterns in places where there is

* Superintendent of Water Works, Cambridge, Mass.

danger of pollution. In cases where the danger is considered serious we are putting in two checks in series, one after the other, and putting them in a pit so that they can easily be kept in order. I believe in this way the conditions can be made very safe. The underwriters are ready to meet water-works men on all these matters, and fully appreciate that our interests are identical. I believe it will be seldom, when we get together in this way, on most anything except meters, that we shall fail to work out the problem in a manner satisfactory to all interests.

MR. JOHN H. FLYNN.* I had occasion not a great while ago to go to a place where they had all these devices which have been spoken of, and the owner laid great stress on the fact that he had wonderful protection because he had three 4-inch pipes going into his building. Two of them, however, were found to be shut off out in the street, and had been for three years; in fact they had never been opened.†

MR. M. F. COLLINS.‡ Mr. Dana has told us here to-day that where there are two sources of supply run into a building the cost of insurance is at the minimum. Now, if in a case where two supplies go into a building, we will say the high and the low service, the parties get their insurance reduced to such a low figure, why shouldn't they be willing to pay for one of the services, when they have two and it reduces their cost of insurance so much? I know of a case in our city where the owner of the building wanted to get the high service put in for nothing, and he was frank enough to tell me that it would bring his insurance down $600 a year, and notwithstanding that he wasn't willing to pay a yearly rental of $25 for a 4-inch connection. I should like to have Mr. Dana explain that.

MR. DANA. I don't know why a high and low service supply should be any different from a single service; the principle is the same. The question is why you should want to make a man pay for putting a system in his building which will extinguish a fire with less water than would be used from the hydrants. I

* Assistant Superintendent, Boston Water Works.

† (*Note by* MR. DANA.) It was supposed that these valves had been left open by the water department, and the discovery that they were closed was made by an insurance inspector.

‡ Superintendent of Water Works, Lawrence, Mass.

don't see that it makes any difference whether he has one or two connections.

Mr. Collins. In the case to which I refer, the man had the low service system in, and the high service was extended down through the business portion of the town at the expense of the public. There was a special appropriation made; the money for the extension was not taken out of the water department. He had all the protection that it was originally intended anybody should have by the low service, which gave in the neighborhood of 65 or 70 pounds pressure; but he asked for the other to be put in on the ground that it would reduce his insurance. Now, if it reduces his insurance why shouldn't he be compelled to pay for it, and why should the insurance engineers be so particular to look after his interests rather than to look after the interests of the water department?

Mr. Dana. I think the same argument will hold, that as matter of principle it doesn't make any difference whether there is one or two services. The question is, if that high service is put in for fire protection, why he hasn't as much right to use it as the next man has. It would be used in case of fire anyway, and if he has a sprinkler system connected with it he will use less water in case of fire than if he hasn't.

Mr. Collins. That doesn't answer the question. My question was, why shouldn't he be willing to pay for the double system, as long as he gets a reduction in his insurance rate? If he gets a reduction of $600 a year in that, why shouldn't he be willing to pay a proportionate part of the expense that the city has to pay?

Mr. Dana. Simply because the high service is put in for public protection.

Mr. Collins. But it isn't public protection when he gets it inside his own building.

Mr. Dana. I don't know why it isn't. If the water puts out any fire it has to go inside the building, of course.

Mr. Flynn. I have a case in mind where a building fell down and carried the pipe with it. It fell down in front of the stairway leading up into the building, and there was a 6-inch pipe running up that stairway. The side walls of the building fell

down and covered the gate in the street, and it was three days before they got the brick away from it, and of course the firemen had gone home long before that. It seems to me that there was a loss there

Mr. Dana. You should have your valve in the street, so you can shut it off from the street.

Mr. Flynn. But we couldn't get at it, because the side wall of the building fell over and covered it up with about 20 feet of brick.

Mr. Dana. They couldn't get at the valves after the San Francisco earthquake, but such cases don't happen very often.

Mr. Flynn. We have to look out for the one case that does happen, — that is when we are proficient in our business.

Mr. Dexter Brackett.* I should like to ask the insurance engineers if they think it would be practicable to shut off fire pipes during the progress of a large conflagration in the business section of Boston, on Washington Street, for example, or on any of the streets that are solidly built upon, in case the buildings were destroyed. It does not seem to me that it would be, and I think there is considerable to be said from the standpoint of the water-works superintendent who objects to putting in pipes of a large size for sprinkler service. The conditions must be taken into account. The conditions that are met by the Manufacturers Mutual Fire Insurance Company, and by other companies that insure largely mill property, where they have yard room in most cases, are entirely different from what they are in a thickly settled city. The quantity of water that is demanded for the sprinkler heads on one floor would be a small part of the quantity of water which would be discharged from a 4-inch or 6-inch main if the building burned, and under those conditions it is probable that the fire service in the immediate neighborhood would be crippled.

The remedy for this may be to have an entirely independent system of street pipes for supplying standpipes and sprinkler systems, independent of the domestic and hydrant service, and this has already been done in the business portion of the city of Boston. Wherever the property is of sufficient value to warrant

* Chief Engineer, Metropolitan Water Works, Boston, Mass.

this expense, it can be done. But I do not believe that the water-works authorities are warranted in crippling the system for the benefit of one comparatively small manufacturer. It may be a question of the comparative value of property. If the property to be protected is a plant worth $1 000 000, and property in the immediate neighborhood is worth but a few thousand, it may be policy to carry one or more 6-inch pipes into a building for supplying sprinklers, but I doubt the desirability of doing this in all cases.

Mr. Dana. Mr. President, in reply to that I would simply suggest that the main point in the use of sprinklers is to prevent a fire from getting large, and we hope some day to have the cities in such shape that we won't have the large fires. When we get the buildings either all fireproof or all equipped with sprinklers, then we won't have any fires which will necessitate shutting off a connection.

Mr. George Cassell.* I am one of the very few men who have had a very wide and sorrowful fire experience. I want to ask Mr. Dana if he thinks the sprinkler system would have had the effect of putting out such a fire as struck my city [Chelsea, Mass.] on the 12th of April last?

Mr. Dana. I don't think it would after the fire got well started, although a brick building properly equipped might have checked it in a certain direction. Sprinklers are supposed to prevent it getting started. The Brown-Durrell building in Boston was equipped with sprinklers and checked the big fire of March 10, 1893, which, but for this, would have undoubtedly been a conflagration.

Automatic sprinklers, together with open (window) sprinklers and blank walls, saved the O'Neill department store in the Baltimore fire and assisted in preventing the spread of the conflagration.

Mr. Cassell. That is just the point, "supposed." The inevitable is going to happen.

Mr. Dana. Not when you get your whole city equipped.

Mr. Cassell. You couldn't have stopped a fire of that kind if you had had all the sprinkler systems and all the steamers in Massachusetts and an Atlantic ocean of fresh water.

* Superintendent of Water Works, Chelsea, Mass.

Mr. Dana. You could if you had had sprinklers in the building where it started.

Mr. Cassell. But, my dear sir, you see you use that little word "if." There is the stumbling block, the "if." It did happen, didn't it?

Mr. Dana. Yes, sir.

Mr. Cassell. It did; and that substantiates my position.

Mr. Dana. What have you done since? You have required that all rag shops hereafter built in Chelsea shall be equipped with sprinklers, in order to prevent it happening again.

Mr. Cassell. That is the law, to be sure, and that brings up another point. You have said to the gentlemen gathered here this afternoon that you have laws governing fire protection systems; and so we have laws in our city, newly made and old, for the protection of property from fire; but the trouble is they are not enforced. Now, if your company, or whoever is interested — and there is a wide field for improvement —will get the coöperation of all the insurance men, and people who install the sprinkler systems, to adhere strictly to your rules and to our rules, we would all be much better off; but experience shows there is very little attention paid to them by some of the insurance people. They come into my city and they think that they are licensed to go into any place where there is a sprinkler system and do just as they please. I am not saying that you are to blame, nor that you are cognizant of the facts, but these are facts. And they had carried it to such a degree that a short time ago I brought some of them before the court and had them fined.

I am only citing this to show that if that hearty coöperation in all things of which you speak,— and by the way, you don't tell our side of it, you only tell your side of it, — if that hearty coöperation in all things pertaining to water supplies was entered into by the insurance people and the water-works people, we could get together and formulate some plan which would be of benefit.

I am glad Mr. Brackett spoke as he did in relation to private fire supplies, because we are well acquainted with the past, and we have had that up in our city, and while we are desirous of doing everything we possibly can do, not only for the corporations but

for the individuals, there is a point at which, when we arrive at it, we must stop. While we are willing to coöperate with the insurance men in furnishing a private fire supply that will not cripple the public supply in the vicinity, when it comes to their asking for something that has a chance to work an injury to the rest of the citizens, there we draw the line. And I say, and say it decidedly, that when the insurance people ask a water-works man to give them a supply of water from a main, in a district not perfectly gridironed, that is equal to the capacity of the main in the street, the man who gives it to them is putting himself in a position to be severely criticised in case of a serious conflagration.

Now, if the insurance people will pay more attention to their own rules and to our rules, they will help us out greatly. For them to make plans for the installation of a private system for a big factory in a city, go ahead with it, and then after they have finished it all come to the water office and ask for a connection, without having found out what our rules and regulations are, I say it is not right. They should come first and get the rules and regulations and the requirements of the city, and not get into trouble and then come and try to force the water department employees or officials to help them out by giving them something that is liable, and very much so, to be to the detriment of the other citizens who are entitled to fire protection.

Mr. Dana. Mr. President, in reply to Mr. Cassell, I will state that the principal reason why I am here to-day is to tell you our rules and to learn your rules and to help bring about better coöperation. I am sure we are always ready to comply with any reasonable rules, but the point is that we think some of your rules are unreasonable.

Mr. Cassell. And I think we have greater reason to believe that some of your rules are unreasonable.

The President. It seems to be the same old question between the insurance men and the water-works superintendents. We have had it up before and are liable to have it up again.

Mr. Collins. Mr. Dana in his paper spoke of going into some city, if I understood him correctly, and finding 200 gates closed.

Mr. Dana. Oh, no; that was not in one city; that was a year's

record in the whole of New England. They were private valves inside of buildings.

Mr. Collins. Well, let me give you an idea how that may have happened. One day I was riding down Canal Street in our city and I saw a man closing a gate on the street. I pulled up my horse and asked him who he was, and he informed me that he represented the underwriters. I told him who I was, and said, "If you want to operate any of our gates it is our duty to furnish a man to go around with you." He said he wanted to make sure they were all-right. I told him that where the authority was divided between the city officials and the mill officials nobody was responsible, and if he wanted to see anything we would give him all the help he needed; but if he went around and operated the gates and closed some of them and left some of them closed, I didn't think it would be the insurance company which would be held responsible, but the water department. So I was wondering whether in those cases of which Mr. Dana spoke it might as likely be the insurance men as the water-works men who were responible.

Mr. Dana. I think you were right; the man had no right to touch the gates without a water-works man present.

Mr. George A. Stacy.* I remember a somewhat similar instance in my town, Mr. President. A man who had charge of a large storehouse came to me one day and said, "We haven't got a main gate wrench up there at the storehouse." I said, "I didn't intend you should have; what do you want it for?" He said, "There is an insurance man here and he wanted to go out and try your gate on the street to see if it was open." I said, "He cannot, unless I go with him." "Well," he said, "the man said there ought to be one there so he could try the gate at any time."

I don't say this as a criticism of all insurance people, but there are some of them going around who, I think, haven't been in the business a great while. I have found the majority of them nice people to deal with. This young man wanted to take a wrench and go out unbeknown to me and handle one of my gates, and I told him, "Any time that the insurance people want to investigate any part of the works, if they will simply notify this de-

* Superintendent of Water Works, Marlboro, Mass.

partment we will drop everything and accommodate them to the best of our ability. They can open and close them as much as they like, but we want to be there when it is done." I think that is reasonable and right. I think he had no business to ask for that wrench, or to go and handle the gate, without me or my representative being there. That creates friction.

Every factory in our city is sprinklered, and there hasn't been an instance yet where the sprinklers haven't done their work, and I know of three or four pretty good-sized structures in the city of Marlboro which, there is no question in my mind, would not be standing there to-day if it wasn't for sprinklers.

On the subject of check valves, I have been interested in what has been said here. In the upper part of the city we have two systems, high and low, and I was rather in doubt how I was going to handle the question when they wanted both pressures available in the factories for their sprinkler service. We believe in doing everything that we can to secure lower insurance rates for our manufacturers, so long as we can do it without crippling the works; so we laid two service pipes, one from the high and one from the low, and put check valves into one outside the building. Those check valves were made by a firm not a great way from Boston. They were put in some years ago; there are quite a number of them; they have been tested many times and they have always worked and been perfectly tight and reliable..

There is one thing more which I recall, that occurred a long while ago, — I suppose they have got beyond that now, and I wouldn't question for a moment the ability of an insurance engineer of the present day to tell what the capacity of a pipe should be, — but there was this one very peculiar thing, that occurred perhaps fifteen years ago, in the upper part of the city, where there was 30 or 35 pounds at that time on the main; they wanted a 4-inch pipe for the sprinkler system, and later, perhaps two or three years afterwards, in the lower part of the city, where there was 95 pounds, for the same service,—practically the same size building with the same number of sprinklers,—I had to put in, or did put in, on request, a 6-inch pipe. I never could reconcile that. I don't mean to say that the insurance people didn't understand what they were doing, but those are the facts.

In regard to a second connection, we have always required the manufacturer to pay for it, and he has always done it willingly. In one case we went through three feet of frost to get the second pipe in by the time the insurance under the one-pipe system expired, and they were willing to pay the extra cost. We haven't had any trouble with our connections or our sprinklers or with the insurance men, except in a very few cases where I think anybody would say they were a little unreasonable. There is very little friction between us, and I think the time is coming when we will all get together. I think we are nearer on this matter of fire service pipes than we were, and everything will come out all right if we have a little patience and keep on with our discussions. I think we are coming to learn more every time we talk these matters over. I think the insurance men are learning, I won't say more than they now know, but a little more about our position, and we are learning a little more about theirs.

PROCEEDINGS.

November Meeting.

Hotel Brunswick, Boston, Mass.,
November 11, 1908.

President Alfred E. Martin in the chair.

The following members and guests were present:

Members.

S. A. Agnew, A. F. Ballou, L. M. Bancroft, G. W. Batchelder, A. E. Blackmer, J. W. Blackmer, C. A. Bogardus, George Bowers, Dexter Brackett, E. C. Brooks, George Cassell, J. C. Chase, C. E. Childs, F. L. Clapp, R. C. P. Coggeshall, M. F. Collins, W. R. Conard, J. H. Cook, G. W. Cutting, Jr., Gorham Dana, E. D. Eldredge, J. H. Flynn, F. F. Forbes, A. N. French, E. V. French, A. D. Fuller, F. L. Fuller, D. H. Gilderson, T. C. Gleason, A. S. Glover, F. H. Gunther, F. E. Hall, T. G. Hazard, Jr., H. G. Holden, J. L. Howard, C. L. Howes, W. S. Johnson, J. W. Kay, E. W. Kent, Willard Kent, G. A. Kimball, G. A. King, L. P. Kinnicutt, H. O. Lacount, E. E. Lochridge, N. A. McMillen, D. E. Makepeace, A. E. Martin, John Mayo, F. E. Merrill, H. A. Miller, William Naylor, F. L. Northrop, H. L. Newhall, E. M. Peck, J. H. Perkins, L. C. Robinson, A. L. Sawyer, E. M. Shedd, C. W. Sherman, G. H. Snell, G. A. Stacy, G. T. Staples, J. T. Stevens, W. F. Sullivan, R. J. Thomas, D. N. Tower, W. H. Vaughn, R. S. Weston, J. C. Whitney, F. I. Winslow, G. E. Winslow. — 72.

Honorary Member.

William T. Sedgwick. — 1.

Associates.

Harold L. Bond Company, by Harold L. Bond; Central Foundry Company, by J. H. Morrison; Chapman Valve Manufacturing Company, by E. F. Hughes; Hersey Manufacturing Company, by Albert S. Glover; International Steam Pump Company, by Samuel Harrison; Ludlow Valve Manufacturing Company, by H. F. Gould; H. Mueller Manufacturing Company, by George A. Caldwell; National Meter Company, by J. G. Lufkin; Pittsburg Meter Company, by F. L. Northrop; Rensselaer Manufacturing Company, by Fred S. Bates and C. L. Brown; Thomson Meter Company, by E. M. Shedd; Water Works Equipment Company, by W. H. VanWinkle, G. W. Browne, and W. H. VanWinkle, Jr. — 15.

Guests.

John McKay, chief engineer, and Charles Rennie, chief inspector, Brooklyn water works, Brooklyn, N. Y.; T. Easten, chairman water board, and I. M.

Lowe, superintendent, Weymouth, Mass.; L. H. Camfel, Boston; W. M. Collins, M.D., and James E. Donnelly, Lowell, Mass.; R. W. Carter, water commissioner, Maynard, Mass.; J. A. Jones, superintendent, Stoneham, Mass., and Dr. H. D. Pease, director State Hygienic Laboratory, Albany, N. Y. — 10.

[Names counted twice — 3.]

Henry Roberts, of Hartford, Conn., president and superintendent of the Hartford water works, his application having been properly endorsed and acted upon, was elected a member of the Association.

Mr. Gorham Dana, manager of the Underwriters Bureau of New England, Boston, Mass., presented a paper entitled "Private Fire Protection and Insurance Rules." The paper was discussed by Messrs. Andrew D. Fuller, Charles W. Sherman, Elbert E. Lochridge, Edwin C. Brooks, Edward V. French, John H. Flynn, Dexter Brackett, George Cassell, and George A. Stacy.

Dr. H. D. Pease, director State Hygienic Laboratory, Albany, N. Y., presented a paper entitled, "Public Water Supplies of the State of New York," which was discussed by Messrs. Robert S. Weston, Wm. T. Sedgwick, Elbert E. Lochridge, and Leonard P. Kinnicutt.

Adjourned.

EXECUTIVE COMMITTEE.

NOVEMBER 11, 1908.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple.

Present: President Martin and members George A. King, D. N. Tower, Robert J. Thomas, George W. Batchelder, M. F. Collins, William F. Sullivan, Charles W. Sherman, L. M. Bancroft, Willard Kent, and George A. Stacy.

James R. Fitzpatrick, general manager Grand Rapids and Hydraulic Company, Grand Rapids, Mich., was reinstated to membership.

Application of Henry Roberts, president and superintendent Hartford water works, Hartford, Conn., was received and he was recommended for membership.

The Secretary was appointed a committee to investigate and report on Bangor as a place for holding the next annual convention.

WILLARD KENT, *Secretary.*

REPORT OF COMMITTEE ON EXHIBITS AT CONVENTION.

NOVEMBER 5, 1908.

WILLARD KENT, *Secretary,*

NEW ENGLAND WATER WORKS ASSOCIATION:

Sir, — The Committee on Exhibits at the annual convention at Atlantic City, hereby makes the following report.

Eighteen associates availed themselves of the opportunity to exhibit goods as follows:

International Steam Pump Company . . .	Worthington meters.
Anderson Coupling Company	Lead connections.
Water Works Equipment Company	Tapping machines, etc.
H. Mueller Mfg. Company	Water-works specialities.
National Meter Company	Meters.
Hersey Mfg. Company	Meters.

Neptune Meter Company	Meters.
National Water Main Cleaning Company .	Samples of pipe.
Builders Iron Foundry	Venturi meters, etc.
Lead-Lined Iron Pipe Company	Lead-lined pipe and fittings.
Pittsburg Meter Company	Meters.
A. P. Smith Mfg. Company	Tapping machines, etc.
Thomson Meter Company	Meters.
East Jersey Pipe Company	Lock-bar steel conduit pipe.
Union Water Meter Company	Meters.
Ross Valve Mfg. Company	Regulators, etc.
Hays Mfg. Company	Water-works specialities.
Fairbanks Company	Scales, hydrants, and valves.

Eighteen exhibits, occupying 500 square feet of space.

Respectfully submitted,

EDWARD F. HUGHES.

OBITUARY.

ARTHUR W. HUNKING died at Helena, Mont., on November 12, 1908, after an illness of a few days.

Mr. Hunking was born in 1851, in Haverhill, Mass. After graduating from the Haverhill High School he took the civil engineering course at the Massachusetts Institute of Technology. His first professional engagement was with Mr. Clemens Herschel, who then had his office in Boston, but he soon joined the staff of the Locks and Canals Company at Lowell, and, except for a year or two spent in the service of the Holyoke Water Power Company, was with that company until 1890. His later service was with the Stillwell-Bierce & Smith-Vaile Company, the Manufacturers Mutual Fire Insurance Company of Philadelphia, and the Massachusetts Cotton Mills in Georgia. In 1905 he became connected with Stone & Webster, of Boston, and was engaged on various water-power development work for them to the time of his death.

He was elected a member of the New England Water Works Association, June 11, 1890.

J. O. A. LAFOREST died December 28, 1907. He was born at Joliette, Quebec, in 1867, and graduated in 1885 from L'École Polytechnique in Montreal He was first employed as an engineer upon the Great Northern Railway of Canada. In 1889 he became assistant engineer of the Montreal Water Works, and in 1894, general superintendent, holding this position for six years. Later he was engineer in charge of construction of water works at a number of towns in Quebec, and from 1903 to 1907 he was in charge of harbor works at Louise Basin, Quebec. He was a member of the Canadian Society of Civil Engineers.

Mr. Laforest became a member of the New England Water Works Association, December 14, 1892.

Claude Pendleton Nibecker, sanitary engineer for the American Water Works and Guarantee Company, died in Pittsburg, Pa., November 10, 1908.

He was born at Westerly, R. I., September 19, 1881. He was graduated from the Massachusetts Institute of Technology in 1903, and immediately thereafter was employed on the experimental filters of the Springfield, Mass., water works. At the close of this work he was engaged by the American Water Works & Guarantee Company, and remained with this company until his death.

Mr. Nibecker was elected a member of the New England Water Works Association on November 14, 1906.

BOOK REVIEWS.

Sewer Construction. By Henry N. Ogden, Professor of Sanitary Engineering, Cornell University. 6 x 9 inches, xii + 335 pages. New York: John Wiley & Sons. Price, $3.00.

This book is supplementary to the author's "Sewer Design," which was published in 1899, and is the result of a course of lectures given to students in civil engineering at Cornell University. It is, therefore, to a large extent, of an elementary nature, but is intended to be, and unquestionably will be, useful to practicing engineers who are for the first time taking up sewer construction work, as well as to students.

Some idea of the contents of the book may be obtained from the titles of the chapters, which are as follows: Terra-Cotta Pipe, Terra-Cotta Pipe (continued), Brick Sewers, Concrete Sewers, Concrete and Brick Sewers, Reinforced Concrete Sewers, Manholes, Catch-Basins, Siphons, Screens, Storm Water Overflows and Regulators, Bell-Mouths, Foundations, Outfall Sewers, House Connections, Surveying, Trenching, Estimates and Costs, Specifications and Contracts.

The treatment of the several subjects is as full as could be expected for students' use, but the practicing engineer would desire somewhat further information on some points, particularly on the design and construction of forms for concrete and reinforced concrete sewers. Some of the statements relating to rapidity of work, too, seem to have been based upon experience prior to the adoption of the eight-hour day, and are hardly applicable to present conditions, at least in New England.

The book is not only well adapted, as a whole, for the classes for whom it was especially prepared, but is well worthy of the perusal of engineers who are actively engaged in this class of work; most of them will find suggestions or ideas which are new or helpful to them.

Reservoirs for Irrigation, Water Power, and Domestic Water Supply. By James D. Schuyler. Second edition, revised and enlarged. 573 pp. $6\frac{3}{4}$ x 10 inches. 381 illustrations, 6 plates. New York: John Wiley & Sons, 1908. $6.00.

This second edition of Schuyler's "Reservoirs" has been much enlarged and largely rewritten. The demand which has resulted in the revision is an evidence of the favor with which this work has been received. The reviewer heartily welcomes the new edition, which contains a great deal of information not easily obtainable elsewhere, and of great interest and value to all who have to do with the design, construction or maintenance of dams or reservoirs. And yet there are many things that may be criticised.

In the first place, the book might more properly be entitled "Dams and Embankments," since it treats almost exclusively of those subjects. Very, very little is said about reservoirs, and nothing whatever about the relative advantages of deep and shallow reservoirs, necessity or otherwise of clearing, grubbing or stripping, estimation of capacity, or other subjects relating to reservoirs rather than dams. Indeed, the chapter titles and section headings are almost invariably *dams.*

The chapters are as follows: Rock-Fill Dams, Hydraulic-Fill Dams, Masonry Dams, Earthern Dams, Steel Dams, Reinforced Concrete Dams, Natural Reservoirs, Miscellaneous.

The basis of the book is a large number of illustrations, largely reproductions of photographs of dams, with a reasonable number of cross-sections and plans, and with comparatively brief sections of descriptive matter. Something like 300 dams are thus described. In some cases the descriptions are fairly detailed, and cover several pages.

There does not seem to be any logical scheme of arrangement of either chapters or sections. The several matters are not treated in chronological order, nor are they grouped at all closely by types or forms. Thus we find gravity and arched masonry dams mixed indiscriminately in the chapter on masonry dams. There are also certain peculiar arrangements, such as inserting a plate showing irrigation canals near Phœnix, Ariz., in a description of dams in Old Mexico; a map of sources of water supply near San Diego, Cal., in text describing dams in India; a cut of the cross-section of the earthern part of the Ashokan dam, without description, in the chapter on Masonry Dams, etc.

The book is made up almost wholly of statistical data and contains very few comments or criticisms upon any of the works described. It would seem as though its usefulness might be largely increased by an analysis of many of the structures, showing wherein their strong and weak points lie, and why they do or do not represent good practice. Some matters which would be of great interest, such as the flood which Professor Williams's Ithaca dam successfully withstood during construction, are not mentioned.

With all this, however, this book contains an immense amount of valuable information and should have a place in the library of every hydraulic engineer. The plates showing comparative sections of the more important masonry dams all over the world, drawn to a single scale, and similar sections of a few large earthern dams, and the table giving cost of reservoir construction per acre-foot of capacity, are especially valuable. It would seem that this table might well be extended by the addition of another column showing the cost per million gallons of capacity, for the benefit of eastern engineers, who never have occasion to work in acre-feet.

Some doubt is, however, thrown on the accuracy of this table by the fact that the cost of the Wachusett Reservoir is here taken as the cost of the Wachusett dam only, neglecting not only the cost of stripping and preparing the reservoir bottom, — which might perhaps well be omitted in a comparison with other reservoirs where no such preparation was made, — but also

the cost of the two dikes, which in effect constituted sections of the dam, equally necessary as the main dam in the construction of a reservoir of the capacity stated.

Most of the illustrations are very good. The book is well printed on good paper, and, considering that it is in effect a new book, contains few typographical errors. It has a good index.

Public Water Supplies. By F. E. Turneaure and H. L. Russell, professors in the University of Wisconsin, with a chapter on Pumping Machinery by D. W. Mead, professor of Hydraulic and Sanitary Engineering, University of Wisconsin. Second edition, revised and enlarged. 808 pp. 6 x 9 inches. New York: John Wiley & Sons. 1908. $5.00.

The first edition of this book appeared in 1901; it has now been revised and brought up to date in illustrating the best modern practice in water-works engineering. The changes in current practice since the first edition have, of course, been most marked in water purification works, but are also of considerable moment in all branches.

This book is primarily a textbook, and a most admirable one. It is designed especially for the use of students in engineering schools. It is, however, none the less valuable as a book of reference for the practicing engineer and water-works man.

To even list the contents of this work as indicated by the chapter headings would occupy more space than is available for this review. It may be stated that the whole subject of water-supply engineering is covered as fully as is possible in the space available, starting with an historical sketch of the development of water-works systems; following with an outline of the quantity of water required and sources of supply; quality of water and examination of supplies; the general principles of water-works design (including a chapter containing substantially all the formulas of hydraulics which are likely to be needed in such works); descriptions of works for the collection, purification, and distribution of water, including pumping machinery; and a few remarks upon general financial considerations in the operation of water works. It may be noted that the application of the principles of economy in the problem of design is also discussed with a reasonable degree of fullness.

Periodical literature has been drawn upon in large measure in preparing much of the matter. It is a satisfaction to note many references to the Journal of this Association, and particularly that the patterns of the Association's Standard Specifications for Cast-Iron Pipe and Special Castings are quoted in some detail. The references are very full, both in the text and in the bibliography which is appended to each chapter.

The book is well illustrated, mostly by reproductions of drawings. The typography and paper are good and the makeup of the volume in every way satisfactory. It is by all odds the most comprehensive and satisfactory single book upon the subject of water works published in the United States, and should be in every water-works library.